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AN EXPLORATORY STUDY ON THE STRATEGIC USE OF INFORMATION TECHNOLOGY IN THE SOURCE SELECTION DECISION-MAKING PROCESS

THESIS

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THESIS

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Acknowledgements

The purpose of this thesis is to analyze the source selection process to determine if segments of the process could be enhanced through the incorporation of information technology. The DoD has begun implementing Electronic Commerce/Electronic Data Interchange to automate the acquisition process into a paperless environment. This is only a small step towards automation. This paper explores how information technology can be further implemented to improve the acquisition process at the source selection decision and award phase.

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Kathy L. Spainhower

Table of Contents

Page

Page

Page

Page

Page

List of Figures

Figure *Page*

Figure *Page*

List of Tables

AFIT/GCM/LAS/98S-9

Abstract

The strategic use of Information Technology in the acquisition field can be very useful in the decision-making process of evaluating alternative solutions during a Government source selection. Current implementation of information technology provides a more tactical approach to systems development. The use of Electronic Commerce/Electronic Data Interchange and the internet to electronically transfer information is only the beginning of the shift towards a more strategic design process for information systems within Government procurement agencies. A schematic model was designed to demonstrate how information technology, such as Decision Support Systems, Expert Systems, and Shared Data Warehousing could assist the SSA in selecting the optimal, or best value solution. In addition, three source selection evaluation models using management science techniques were designed and developed using Microsoft Excel software. The Sealed Bidding, FAR Part 14, and Competitive Proposal, FAR Part 15 models implemented Integer Linear Programming through Microsoft Excel's SOLVER option. The AFFARS Appendix AA/BB model implemented the use of the multi-criteria Analytical Hierarchy Process.

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1. Introduction

1.1 Background

Acquisition Reform mandates have led Department of Defense (DoD) policy makers and acquisition personnel to continually search for new initiatives to improve the acquisition process. Reducing acquisition lead-time is a major component to ensure quality products are delivered to the right place, in the right quantity, and at the right time (Dobler and Burt, 1996: 42). As the DoD budget continues to shrink, acquisition personnel must initiate strategic measures to maximize the benefits received from every tax dollar spent. Policies which implement philosophies such as using Cost as an Independent Variable (CAIV) to assist with reducing costs; using "Past Performance" as an evaluation criterion to hold a contractor accountable for his/her poor past performance to reduce the Government's risk; and using a Statement of Objectives rather than a Statement of Work to shift design and development risk from the Air Force to the contractor are just some examples in which the DoD and the Air Force are changing their strategies in the acquisition field. These strategies, and others like them, have increased the complexity for decision-makers in their attempt to select the best source of supply in

many types of acquisitions. In his book, Decision Making in the Purchasing Process, Phillip White states, "we (as purchasing managers) must develop realistic and flexible guidelines that recognize the (evaluation) factors involved and deal with them in an informed way" (White, 1978: 9). The increasing complexities from these ever-changing strategies augment the need for a more systematic approach to assist in the decision-making process during source selections. The purpose of this research is to explore various strategically-focused information technology tools which might be utilized in the source selection process in an attempt to move the acquisition field from a reactive or tactical focus to a more proactive or strategic focus. The flow of information required by personnel in the source selection decision-making evaluation process is analyzed to see how information technology can be incorporated to provide more reliable and accessible data. The evaluation process is then supported using a commercially available software tool for solving "optimization" problems. This software tool is examined to determine the extent it can assist decision-making in the source selection process.

1.2 General Issue

H. B. Twyford of the Otis Elevator Company, in one of the earliest books focused on purchasing, wrote:

> A (purchasing) staff which is entirely unsympathetic with the particular needs of the users of the material will fail to grasp what is one of the most essential things for their department. They will be dealing with papers and accounts instead of with men and things. (Dobler and Burt, 1996: 7)

According to Dobler and Burt, companies in the commercial market have historically focused their profit-gaining strategies toward efforts to improve marketing,

R&D, finance, and operation functions. Until approximately the 1970s, commercial purchasing personnel possessed neither the skills nor the aptitude to assist the purchasing function achieve its fullest contribution towards the success of the organization. The purchasing department was responsible for a significant portion of the costs of goods sold, and purchased materials were the cause of a large portion of a companies quality problems. "By the late 1980s, material costs made up approximately 60 percent of the cost of goods sold in the United States" (Dobler and Burt, 1996: 3-38). As a result, the impact of purchasing and materials management on a company's assets became extremely significant and very visible (Dobler and Burt, 1996: 3-38). To remain competitive, companies began to look at the purchasing process as an area to cut costs. "Two major paradigm shifts occurred: (1) a shift from a focus on internal processes to value-added benefits and (2) from a tactical to a strategic focus" (Dobler and Burt, 1996: 9). Successful companies began to view their supply or acquisition strategies as a strategic weapon as important as their marketing, conversion and financial strategies (Dobler and Burt, 1996: 9). "The extent to which the purchasing function will continue to contribute to the achievement of organizational goals depends on the ability of purchasing managers to question the conventional ways of doing things and to keep up with, and actively develop, new ideas. Continued systematic review of the variables important in purchasing decisions provides an essential tool to accomplish this objective" (White, 1978: 6).

Similar to the commercial market's concern to increase profit, the DoD is concerned with its ability to control and reduce costs. The DoD is similar to the commercial market in its attempt to acquire quality products while controlling costs, with

one major difference: its strategic focus on decision-making. This exception is clearly evident in the design and implementation of information technology systems within the acquisition arena. In a 23 Oct 97 Background Paper on Revolution in Business Affairs (RBA), SAF/AQXA discusses Dr. Hamre's (DepSecDef) seventeen "Management Reform Memorandums" designed to initiate a "revolution in business affairs" across the Department of Defense. These memos were written in response to Secretary Cohen's call for infrastructure reductions in the Quadrennial Defense Review. Management Reform Memorandum #2 requires the movement to a Paper Free Contracting Process by 1 Jan 2000 (SAF/AQXA, 1997). These memorandums were the result of the implementation of Section 30 of the Office of Federal Procurement Policy (OFPP) Act (41 U.S.C. 426) which requires the development and implementation of an automated system to create a paperless environment.

Review of the Federal Acquisition Regulations (FAR), Subpart 4.504 discusses the functions of the Federal Acquisition Computer Network (FACNET), which according to FAR 4.500 is the current Government Electronic Commerce/Electronic Data Interchange (EC/EDI) system implemented as required by Section 30 of the OFPP Act. According to the FAR, the purpose of the automated system is to transmit and store information electronically. FAR 4.504 states FACNET's functions:

> (a) For agencies--
> (1) Provide widespread public notice of contracting opportunities, and issue solicitations;
> (2) Receive responses to solicitations and associated requests for information;
> (3) Provide widespread public notice of contract awards and issuance of orders (including price);
> (4) Receive questions regarding solicitations, if practicable;

(5) Issue contracts and orders, if practicable;
(6) Initiate payments to contractors, if practicable; and
(7) Archive data relating to each procurement action.
(b) For the private sector--
(1) Access notices of solicitation;
(2) Access and review solicitations;
(3) Respond to solicitations;
(4) Receive contracts and orders, if practicable;
(5) Access information on contract awards and issuance of orders; and
(6) Receive payment by purchase card, electronic funds transfer, or other automated means, if practicable.

On 12 July 96, Ms. Eleanor R. Spector, Director of Defense Procurement, Office of the Under Secretary of Defense signed a letter to the Directors of Defense Agencies mandating the use of a Standard Procurement System (SPS) as the standardized automated procurement system for use by the DoD procurement offices. According to the Navy, SPS is "the next generation of procurement application software, designed to link acquisition reform and common DOD procurement business processes with commercial best practices and advances in electronic commerce" (DoD SPS, 1998). SPS is an integrated system consisting of : (DoD SPS, 1998)

(1) Licensed access to the contractor-furnished SPS application software;
(2) Government furnished data;
(3) A relational data base management system;
(4) Installed government operating environment;
(5) System connectivity (e.g., local area or wide area network);
(6) A Shared Data Warehouse (SDW).

The SPS is currently being designed to support DOD procurement functions that acquire systems, supplies and services. The vision is for data input to begin with receipt of

a requirement and to finish at contract close-out. The standard, automated procurement functions performed during this process include: (DoD SPS, 1998)

(1) Collecting the requirements;
(2) Determining the appropriate method for acquiring systems, supplies or services;
(3) Soliciting and selecting sources;
(4) Awarding, reporting, modifying, terminating and closing out contracts and other instruments;
(5) Inspecting and accepting systems, supplies or services;
(6) Monitoring and administering quality assurance actions and programs;
(7) Production and engineering surveillance;
(8) Property administration;
(9) Determining amounts payable;
(10) Monitoring, approving and tracking payments.

While the current use of these EC/EDI technologies in the acquisition field are broad in scope, attempting to standardize and unify Government acquisition offices, the effort is still limited in application. An information system is defined as "a set of interrelated components that collect (or retrieve), process, store, and distribute information *to support decision-making* and control in an organization" (Laudon and Laudon, 1995: 6). In addition, information systems assist managers and employees to analyze problems, visualize complex subjects, and create new products (Laudon and Laudon, 1995). According to FAR 2.101, information technology is defined as "any equipment, or interconnected system(s) or system(s) of equipment, that is used in the automatic acquisition, storage, *manipulation*, management, movement, control, display, switching, interchange, transmission, or reception of data or information by the agency" (FAR 2.101).

Using an analogy to H. B. Twyford's quote on purchasing, Government personnel responsible for the implementation of information technology in the contracting/

acquisition field must remember to "deal with men and things instead of papers and accounts" (Dobler and Burt, 1996: 7). The current SPS design (version 4.0) has a limited ability to assist the SSA with the manipulation and analysis of evaluation information for decision-making. In offer evaluation, the system allows the contract specialist to evaluate quote information from all vendors, simultaneously, by line item and provides a method for totaling calculations. In addition, SPS can generate and analyze price history for a product by conducting price searches within the database to locate previous acquisitions of the same product (DoD SPS, 1998). With proper planning and design, information technology can be used to strategically take the process further into analyzing and manipulation of the information collected, compiled, and stored. The creation of an automated information system, such as FACNET, for the transmittal and receipt of information, and storage of these transactions demonstrates a tactical focus of information technology in the contracting field. A paradigm shift in the design and development of information technology systems to a more strategic focus is required (Dobler and Burt, 1996: 7). The SPS design and development is only the beginning of the shift from a tactical to strategic approach to decision-making in the acquisition field. Information technology can process and manipulate data to assist with decision-making. Numerous software tools can choose an optimal solution from among different alternates using multi-criteria evaluation factors, perform risk assessments, and forecast the probability of an event occurring, such as the likelihood of a project failure if a contract is awarded to a specific contractor. Implementation and use of these tools in a systematic method can

help shift Government purchasing from a tactical, reactive mode of operation to a more strategic, proactive mode of operation.

1.3 Specific Problem

The specific focus of this research is to survey current information technology components to find tools which can strategically assist, either directly or indirectly, the Source Selection Authority (SSA) with the evaluation and analysis of alternative sources in the decision-making process of a competitive source selection. Only components which can enhance the flow of information into the source selection evaluation process to assist with the manipulation or processing of required evaluation data will be identified. Various software programs can manipulate data to find an optimal solution using multi-criteria evaluation factors. Numerous specialized mathematical programming packages, such as LINDO (Linear Interactive Discrete Optimizer), MPSX (IBM's Mathematical Programming Systems Extended), AMPL (A Mathematical Programming Language), CPLEX (first commercial implementation of simplex method written in "C" programming language) and MathPro, can solve optimization problems without using a spreadsheet (ILOG CPLEX, LINDO, and IBM, 1998). These programs are typically used by researchers and businesses to solve extremely large problems that do not conveniently fit into a spreadsheet (Ragsdale, 1997: 44). Microsoft Excel's SOLVER, a spreadsheet modeling and decision analysis add-in option tool built by Frontline Systems, was selected for baseline development in this research for several reasons. The spreadsheet is a convenient information technology platform for baseline design since the majority of price/cost analysts within the contracting field currently use spreadsheets to analyze

contractor proposals for reliability and realism. The probability of a contract's source selection information exceeding the capability of a spreadsheet seems unlikely. The SOLVER program was also chosen since it comes as a standard option to the Microsoft Excel programs, Windows 95 and Windows 97. The Microsoft Excel package contains numerous mathematical modeling capabilities, including solving linear, integer linear, and nonlinear programming problems; goal programming and multiple objective optimization problems; and multi-criteria decision-making and analytic hierarchy process problems. These features allow for flexibility and adaptability in developing the baseline models. In addition, Microsoft Excel is a commercially available software program which is currently used, or easily obtainable, by most DoD/Air Force contracting offices.

1.4 Investigative Questions

Two main investigative questions are researched in this thesis.

1) Can a schematic model be designed to identify areas where information technology can improve the flow of information into the source selection evaluation process and expand the present tactical approach to evaluation of alternatives into a more strategic approach?

2) Can a baseline model be designed, based upon Microsoft Excel SOLVER, to assist the SSA in choosing the optimal or best alternative source in a competitive source selection?

1.5 Overview of the Thesis Structure

Chapter 2 surveys literature relevant to the evaluation of alternative sources during the government's competitive source selection process. This process includes sealed bidding, as defined in FAR Part 14; competitive proposals, as defined in FAR Part 15; and formal source selections, as defined in AFFARS Appendix AA and BB. This review is essential to determine the contractual and legal evaluation boundaries for development of the Microsoft Excel SOLVER models. In addition, Chapter 2 surveys literature relevant to finding "strategically focused" information technology components to automate the flow of information into the source selection process and enhance the SSA's, and contracting officials, ability to make a better decision by using a more integrated, systematic approach. Chapter 2 concludes with a discussion on the evaluation aspects of the Microsoft Excel SOLVER program. Chapter 3 discusses the general approach used to develop the schematic model for demonstration of how information flow into the source selection evaluation process can be automatically generated and input into Microsoft Excel SOLVER for manipulation and analysis to enhance the overall source selection process. The primary method of research for the development of the schematic model was a case study approach to survey and evaluate primary and secondary literary sources on information technology systems which could have the potential to assist in the source selection decision-making process. The primary method of research for the design and development of the Microsoft Excel baseline models was a grounded theory approach. Grounded theory was chosen as it allows for the development and analysis of the model simultaneously, and provides the researcher the opportunity to correct deficiencies as they

occur. Chapter 3 concludes with a discussion on the procedures for analysis and verification of the baseline models. The baseline models, one for sealed bidding, one for competitive proposals, and one for AFFARS Appendix AA/BB source selections, are evaluated for ease of communication, reliability, auditability, and modifiability. Chapter 4, Model Development and Analysis, addresses the findings of the data collected and analyzed during model development for both the schematic and SOLVER models. An analysis of a single theoretical schematic model is discussed as it relates to the literary research. A discussion of the design and development of the Microsoft Excel SOLVER baseline models, observations and problems which occurred during development due to contracting regulatory constraints, and each models adaptability to multiple types of evaluation criteria based on communication, reliability, auditability, and modifiability are addressed. Chapter 5 contains the conclusions and recommendations for further research resulting from the study of the problems identified in this thesis.

2. Literature Review

This chapter is divided into three main sections, 1) A survey of literature concerning the competitive source selection process, specifically the basis of award in various types of government acquisitions; 2) A survey of literature concerning information technology components and tools useful for collecting and flowing information into the source selection process for manipulation and analysis during final evaluation to allow for more informed decisions; and 3) A survey of literature discussing Microsoft Excel SOLVER as the model base for the manipulation and analysis of the source selection information flowing from the schematic model into the decision-making process. Microsoft Excel features, such as scoring models for multi-criteria decision-making, the analytical hierarchy process, mathematical modeling and optimization tools, and decision analysis techniques are discussed in relation to the source selection process and the constraints placed upon the model due to contracting policy and regulations. This information is important to understand the mechanics behind the Microsoft Excel SOLVER software program. Chapter 2 concludes with a discussion of how the source selection policies and regulations, the flow of information into the source selection process, and the manipulation and analysis of the data using the Microsoft Excel SOLVER program can benefit the Government by shifting from a tactical focus to a more strategic focus on decision-making.

2.1 Acquisition Overview and Brief Explanation of Key Terms

2.1.1 Competitive Source Selection Process. The two primary competitive procedures are sealed bidding and competitive proposals. Competitive procedures in the source selection process entail the use of "full and open competition." The Office of Federal Procurement policy Act, 41 U.S.C. 403 (7), defines "full and open competition to mean all responsible sources are permitted to submit sealed bids or competitive proposals on a procurement" (Cibinic and Nash, 1986: 288). In addition, full and open competition may be limited by excluding particular sources, such as in small business or labor-surplus set-asides; or when the agency head determines to exclude an incumbent contractor to establish or maintain alternative sources (FAR 6.3). Seven specific types of procurements are authorized by statute to use other than full and open competition. Contracts using procedures under these seven exceptions, as defined in FAR 6.302, are not incorporated into the context of this research. These seven types of procurements are considered non-competitive, and usually have only a single offeror (or alternative) proposing for award of the contract. These procurements use negotiated procedures and are considered sole source acquisitions. For the purposes of this investigation, only procurements utilizing full and open competition, or limited competition, are analyzed. Limited competition includes acquisitions in which competition is restricted due to a small-business or a small disadvantaged business set-aside.

2.2 Basis for Contract Award

Contract award in a Government acquisition is based upon the complexity of the acquisition and the need to discuss a offeror's proposal. In non-complex acquisitions,

which do not require discussions, award can be made to the lowest priced offeror which has met the material requirements of the invitation for bid; the offeror has proposed exactly what was asked for without any significant deviations. When the complexity of the acquisition increases to warrant discussions, the SSA has more options to select from as the basis of award. Award can be made on the basis of selecting the lowest priced, technically acceptable offeror, in which the proposals are first evaluated to determine which offerors have met the minimum technical requirements of the solicitation, and award goes to the lowest priced offeror whose proposal meets the minimum. A second option available to the SSA is to award to the offeror whose proposal is determined to be the best value to the Government. As with the lowest cost, technically acceptable basis for award, the basis for a best value award first determines which offerors are technically acceptable based upon the minimum requirements stated in the solicitation. However, using the best value basis for award, the SSA has the latitude to chose a higher priced proposal if its increase in cost can be justified by its technical superiority in relation to the lower priced proposals within the technically acceptable competitive range. Three basic source selection procedures are discussed in the next sections in relation to their basis for award. These include sealed bidding, as defined in FAR Part 14; Competitive Proposals, as defined in FAR Part 15; and Formal Source Selections, as defined in AFFARS Appendix AA/BB.

2.2.1 Sealed Bidding (FAR Part 14). With sealed bidding techniques, the basis for award is to evaluate the offers and award to the responsible offeror whose bid is the most advantageous to the Government, considering only price and the price-related

factors (FAR 14.101(d)(e)). In essence, the award goes to the overall, lowest priced offeror whose bid conforms to the requirements of the invitation for bids (IFB). Depending upon the circumstances of the procurement, the evaluation process to determine which offeror is offering the lowest cost to the Government varies from a simple to a complex task. The complexity of the evaluation increases in relation to the number of items being procured, and whether a single aggregate award or multiple awards will be issued. In addition, price adjustment clauses allowing for discounts or economic price adjustments increase the complexity of the award evaluation. When the evaluation criteria contain "price-related factors," such as transportation costs, life cycle costs, taxes, options, or Buy American Act provisions, a thorough examination of the bids to determine the most advantageous award can become quite complicated. The contracting official must also analyze the bids for unbalanced bidding (bidding high on some items and low on others) or bids which are front end loaded (bids which enable an offeror to recover money in advance of the work performed by bidding high on the earliest delivered work and low on work delivered last) (Cibinic and Nash, 1986: 442-443). As previously stated, the award can be made on an "all-or-none" or aggregate basis or can be divided into multiple awards if it is determined to be economically advantageous to the Government and the provision at FAR 52.214-22, "Evaluation of Bids for Multiple Awards" is included in the IFB. Some offerors propose various combinations of split awards which must be taken into consideration. For evaluation purposes, when making a determination to issue a single or make multiple awards, a $500 administrative fee is added to the costs of each individual contract to be awarded under the IFB if multiple awards appear feasible. This

$500 fee is a predetermined cost the Government will incur due to the additional costs of issuing and administering multiple contracts. Individual awards are based upon the items or combination of items that result in the lowest aggregate cost to the Government, including the assumed administrative fees (FAR 14.201-8 (c)). The contracting official must meticulously evaluate all proposals to determine the most advantageous award alternative for the Government, and must complete this task within the bid evaluation time.

2.2.2 Competitive Proposals (FAR Part 15, and AFFARS Appendix AA/BB).

2.2.2.1 General Information. In competitive acquisitions using negotiated procurement procedures, the intent is to minimize the complexity of the solicitation, evaluation, and the source selection decision-making process, using procedures designed to encourage impartial and comprehensive evaluations of proposals. The intent is to use processes and procedures allowing for the selection of the proposal representing the best value to the Government (FAR 15.002 (b)). FAR 2.101 defines "best value" as "the expected outcome of an acquisition that, in the Government's estimation, provides the greatest overall benefit in response to the requirement" (FAR 2.101). According to FAR 15.304, the SSA has broad discretion in selecting the evaluation factors and subfactors that apply to an acquisition but must include price or cost, quality, and at least consider past performance as evaluation factors. A complete citation regarding evaluation factors and significant subfactors for competitive negotiated acquisitions (FAR 15.304) can be seen in Appendix A.

2.2.2.2 FAR Part 15, Competitive Proposals. The use of competitive proposals lends flexibility to the source selection evaluation process. Award can be made on the basis of lowest-priced offeror, lowest-priced, technically acceptable offeror, or best value to the Government. If the acquisition is noncomplex so as to warrant award without discussions to the lowest-priced offeror, generally sealed bidding procedures are used. Whichever method is used, it must be published in the solicitation, along with the evaluation criteria, so all potential offerors will know how their proposals are being judged (FAR 15).

2.2.2.2.1 Decisional Rules. Various systems are used to determine the measures of relative importance for the criteria selected for evaluation (Cibinic and Nash, 1986: 548). Two decision rule techniques are used to accomplish this task. These are general guidelines on the relative importance of various criteria or developing a mathematical system. DARCOM Pamphlet 715-3, dated 24 Oct 80, paragraph 4-4, states:

> Relativity of each criterion to the total mission requirement must be established in order to summarize the scores. The decisionmaker may do this by weighting the criteria, by priority or trade-off statements, by judgmental decision rules, or a combination of these. Weighting would involve an assignment of relative importance among the criteria by breaking up a constant sum (typically 100 or 1000 points). For source officials who do not want to specify numerical relationships, the criteria may be related by priority statements and the scores combined by judgment using these priorities rather than numeric formulas using weights. For example, in a priority statement "cost" may be said to be slightly more important than "management" but slightly less than "operational suitability." A decision rule would tell how to deal with a factor under varying conditions. For example, a decision rule might be "if management is rated anything less than satisfactory, the entire proposal is unacceptable," or "if the

> proposed price is 30-percent higher than the Government estimate, it will be judged as being potentially unrealistic, the cost score will be penalized, and the technical proposal will be reevaluated to see if there is some misunderstanding of the requirements." In order, then, to provide a base for the evaluation, a precise definition of each established criterion must be prepared in narrative form to indicate what it is and how it is to be used, and a description of the alpha or numeric standard indicating the desired performance for each major element, and the relationship among factors and subfactors. Definitions should be either included in, or appended to the selection plan. (Cibinic and Nash, 1986: 548)

The SSA can choose which decisional process to use for evaluation. The goal is to choose a process providing a sound and logical decision. A system using a generalized priority statement provides flexibility in the evaluation, while a purely mathematical weighting system is quite restrictive. Systems are composed of one or more of the following decisional rules: Fixed Weights; Variable Weights; Tradeoff Analysis; Go, No-Go; and Lowest-Priced Acceptable Proposal (Cibinic and Nash, 1986: 548-554).

2.2.2.2.1.1 Fixed Weights. In this method, fixed weights are assigned or attributed to each evaluation factor. The simplest, and most common method of assigning fixed weights is by percentage distribution. Percentage distribution distributes weights among the major areas and elements based upon a 100 percent total score. Another common mathematical system is the point system. The point system assigns points on the basis of importance of the criteria. Table 1 compares the percentage distribution system and the point system.

Variations of the fixed weight system are also used. One example of a variation is to determine the relative weight or importance of the evaluation factors in relation to their expected impact on life cycle costs (Cibinic and Nash, 1986: 550-551).

Table 1

Fixed Weights System
An Example of Percentage Distribution and Point System
(Cibinic and Nash, 1986: 549-550)

Evaluation Criteria	Percentage Distribution	Point System
I. Adequacy of Technical Proposal	60%	200 pts.
a. Literature Search and investigation methodology	20%	100 pts.
b. Proposed sources of information	15%	35 pts.
c. Plan for Assessing Literature	15%	35 pts.
d. Presentation of Findings	10%	30 pts.
II. Personnel Qualifications	40%	100 pts.
a. Technical Experience of project staff	25%	70 pts.
b. Educational Qualifications	10%	20 pts.
c. Qualifications of Consultants	5%	10 pts.

2.2.2.2.1.2 ***Variable Weights.*** In certain situations, the SSA requires more flexibility in the weighting of factors than fixed weight affords. Variable weights are commonly used in situations where the SSA decides that cost or price should remain flexible to become more important when technical proposals are of relatively equal weight (Cibinic and Nash, 1986: 551).

2.2.2.2.1.3 ***Tradeoff Analysis.*** Tradeoff analysis evaluates differences in technical and management proposals to determine whether or not the differences justify paying a higher cost or price. Ordinarily, technical and management factors are scored using a point system, and the differences between the technical proposals are compared to the differences in the cost/price proposals to measure the

cost/benefit of a tradeoff. Tradeoff analysis allows an award on the basis of best value rather than lowest cost. If a solicitation is silent on the relative importance of cost in relation to the technical criteria, then the cost and technical criteria are determined to have equal importance. The SSA has great latitude in determining the use of technical and cost evaluation information. The SSA can make cost/technical tradeoffs which are consistent and rational based upon the established evaluation factors in the solicitation. Cost factors are not scored because the relative weight in a cost/technical tradeoff can be determined only after the contracting official has analyzed the relative worth and significance of the technical proposals. FAR 15.101-1 states the following regarding the tradeoff process:

> (a) A tradeoff process is appropriate when it may be in the best interest of the Government to consider award to other than the lowest priced offeror or other than the highest technically rated offeror.
> (b) When using a tradeoff process, the following apply:
> (1) All evaluation factors and significant subfactors that will affect contract award and their relative importance shall be clearly stated in the solicitation; and
> (2) The solicitation shall state whether all evaluation factors other than cost or price, when combined, are significantly more important than, approximately equal to, or significantly less important than cost or price.
> (c) This process permits tradeoffs among cost or price and non-cost factors and allows the Government to accept other than the lowest priced proposal. The perceived benefits of the higher priced proposal shall merit the additional cost, and the rationale for tradeoffs must be documented in the file. (FAR 15.101-1)

2.2.2.2.1.4 Go, No-Go. In a Go, No-Go situation, the criteria are evaluated on a "pass/fail" or "adequate/inadequate" basis. A passing or adequate score means the offeror has met the minimum requirement for selection. An example which uses Go, No-Go techniques is award to the lowest cost, technically acceptable offeror. The technical proposal is first evaluated on a

pass/fail basis, and award is then made to the offeror with the lowest cost/price who has a passing score (Cibinic and Nash, 1986: 553-554).

2.2.2.2.1.5 Lowest-Priced Acceptable Proposal.

This technique is similar to the Go, No-Go method in that it utilizes the Go, No-Go techniques by applying them to the entire technical and management proposal. After evaluation, unacceptable proposals may still be included within the competitive range, and given a second chance to become acceptable. Award is made to the acceptable offeror with the lowest evaluated cost/price (Cibinic and Nash, 1986: 554). FAR 15.101-2 states the following regarding the lowest price technically acceptable source selection process:

> (a) The lowest price technically acceptable source selection process is appropriate when best value is expected to result from selection of the technically acceptable proposal with the lowest evaluated price.
> (b) When using the lowest price technically acceptable process, the following apply:
> (1) The evaluation factors and significant subfactors that establish the requirements of acceptability shall be set forth in the solicitation. Solicitations shall specify that award will be made on the basis of the lowest evaluated price of proposals meeting or exceeding the acceptability standards for non-cost factors. If the contracting officer documents the file pursuant to 15.304(c)(3)(iii), past performance need not be an evaluation factor in lowest price technically acceptable source selections. If the contracting officer elects to consider past performance as an evaluation factor, it shall be evaluated in accordance with 15.305. However, the comparative assessment in 15.305(a)(2)(i) does not apply....
> (2) Tradeoffs are not permitted.
> (3) Proposals are evaluated for acceptability but not ranked using the non-cost/price factors.
> (4) Exchanges may occur.

2.2.2.2.2 Scoring Methods. Scoring methods prescribe the procedures used to compare each offeror's proposal against the Government's

requirements and to rate them in relation to competitor's proposals. "The method of comparison need only have a rational basis and be applied in a good faith manner" (Cibinic and Nash, 1986: 555). According to FAR 15.305(a), evaluations may be conducted using any rating method or combination of methods, including color or adjectival ratings, numerical weights, and ordinal rankings. The guidance on scoring methods varies among Government agencies. DoD Directive 4105.62 requires a narrative statement as part of the evaluation, but the regulation is adaptable as to the scoring techniques used. DoD Directive 4105.62, paragraph E.4.c. states:

> There is no prescribed methodology for rating. Past practices include color coding, numerical, and plus or minus checks. The important thing is not the rating methodology but the consistency with which it is applied to elements of proposals and among proposals to ensure a thorough and fair evaluation. Evaluators must be well rounded in their field of expertise and be able to apply mature professional judgment.....evaluators must support the rating assigned with a concise narrative that addresses strengths, weaknesses, and risks in the proposal. (Cibinic and Nash, 1986: 555-556)

Various types of scoring systems include adjective ratings; numerical scores; narratives; and ranking (Cibinic and Nash, 1986: 555-556).

2.2.2.2.2.1 Adjectival Ratings. Adjective ratings describe the quality of a proposal in terms of words or symbols representing words. All adjectival rating systems compare the proposal against the contract requirements and provide information using the words or symbols to describe the extent of compliance or problems represented. The Air Force uses a color coding system, a descriptive adjective system, and a symbol system (described in paragraph 2.2.2.3.1 below) as part of its formal source selection procedures. A

number of source selection manuals suggest using adjectival systems for presenting source selection evaluation details to the SSA, even if another type of scoring system was used for evaluation (Cibinic and Nash, 1986: 558).

2.2.2.2.2.2 Numerical Scores. Numerical point scores may be used to evaluate proposals. The Air Force discourages the use of numerical weighting of evaluation criteria in its formal source selection procedures due to difficulty supporting modest differences in technical merit (AFFARS BB-304 (c)); for example, it is difficult to measure and support an offeror's proposal as being 49% or 51% better than an evaluation criteria when the standard for acceptability is 50%. The validity of evaluation by numerical point scores may be scrutinized. In a decision by the Comptroller General, in Bunker Ramo Corporation, 56 Vomp. Gen. 712 (1977), 77-1 CPD 427, the Comptroller stated:

> Numerical point scores, when used for proposal evaluation, are useful as guides to intelligent decision making, but are not themselves controlling in determining award, since these scores can only reflect the disparate, subjective, and objective judgments of the evaluators. Whether a given point spread between competing offers indicates the significant superiority of one proposal over another depends on the facts and circumstances of each procurement, and while technical scores must of course be considered by SSAs, such officials are not bound thereby. (Cibinic and Nash, 1986: 559)

There are numerous variations of numerical scoring systems. Normally numerical scoring systems assign a score value ranging from 0 to 10. Table 2 describes a cross reference between a sample numerical and adjectival scoring system.

Table 2

Sample Cross Reference of Numerical and Adjectival Scoring Systems (Cibinic and Nash, 1986: 559-560)

Numerical Score	Adjective Rating	Definition/ Evaluation
10	Excellent--	(innovative, comprehensive and complete in all details, meets all requirements and objectives without "gold plating")
9	Very Good--	(substantial response in clearly definable detail, meets all critical requirements)
7	Average--	(generally meets minimum requirements)
6	Poor--	(lack of essential information to substantiate data presented)
5	Unsatis- factory--	(lack of understanding of requirements or omissions in major areas)
0	No data--	

In addition, Comptroller General decisions have discouraged the use of procedures which "distort" scores. A system which assigns scores by using a formula runs the risk of distorting evaluation results. Two examples of numerical scoring methods that tend to distort data are "spread scoring," which involves assigning maximum points to the offeror with the lowest cost and zero points to the offeror with the highest costs; and mathematical or statistical analysis techniques, which assign maximum points to the offerors whose proposed costs are closest to the Government estimate and to penalize offerors in relation to the amount of deviation their costs are from the estimate. Since this penalty was applied both above and below the Government estimate, the second method tends to penalize the lowest cost/priced offeror (Cibinic and Nash, 1986: 561).

2.2.2.2.2.3 ***Narrative.*** Narrative statements are required by DoD Directive 4105.62. A narrative evaluation must be used in conjunction with other scoring methods to indicate strengths and weaknesses. The goal of the narrative evaluation is to enhance communication on specific information regarding relative advantages and disadvantages to the SSA (Cibinic and Nash, 1986: 561).

2.2.2.2.2.4 ***Ranking.*** The direct ranking of proposals, without the aid of numerical scores, has been upheld by Comptroller General Decision B-205380, 82-2 CPD 37 (1982) for Development Associates Inc. Numerical scores do not "transform the technical evaluation into a more objective process" (Cibinic and Nash, 1986: 561).

2.2.2.3 AFFARS Appendix AA/BB Source Selections. The same rules and regulations as described in paragraph 2.2.2.2 above govern acquisitions using AFFARS Appendix AA and BB, however these appendices supplement the information provided in the FAR to require a more stringent process on the AF. AF acquisitions over $5 million are required to use a more formal process of source selection. Depending on the dollar value and/or the criticality of the acquisition, either Appendix AA or Appendix BB will be used. Appendix AA has more steps in the overall process and higher visibility, but the evaluation processes for Appendix AA and BB are essentially the same. Both procedures establish their evaluation criteria on a hierarchical basis and use an adjective rating system which implements a color coding system.

2.2.2.3.1 Adjectival Coding System.

2.2.2.3.1.1 Colors. The color coding system for Essential Characteristics or Baseline Requirements is described in Table 3.

Table 3

AF Color Rating System
Color Coding for Essential Characteristics or Baseline Requirements
(AFFARS Appendix BB-304) and *(Cibinic and Nash, 1986: 558)

COLOR	RATING	DEFINITIONS
Blue	Exceptional	Exceeds specified performance or capability in a beneficial way to the Air Force; high probability of success*; no significant weaknesses.
Green	Acceptable	Meets standards; good probability of success*; weaknesses can be readily corrected.
Yellow	Marginal	Fails to meet standards; low probability of success*; however, significant deficiencies are correctable.
Red	Unacceptable	Fails to meet a minimum requirement of the RFP and the deficiency is uncorrectable without a major revision of the proposal.

Recent policy changes have led to the segregation of "Essential Characteristics or Baseline Requirements" from "Minimum Mandatory Requirements" for determining the competitive range. As a result, there are now two separate color coding schemes for evaluation. Minimum Mandatory Requirements are the initial pass/fail criteria used to reduce the number of proposals evaluated in depth by eliminating offerors from the competitive range. The color coding scheme for the Essential Characteristics is shown in Table 3; the color coding scheme for the minimum mandatory requirements is a pass/fail

or a go/no go evaluation, since the offeror is evaluated as either green for acceptable, met the minimum requirement or red, does not meet the minimum requirement. A source selection may have essential characteristics or baseline requirements or a combination of minimum mandatory requirements and essential characteristics or baseline requirements (AFFARS Appendix BB-203 (2)(i)). AFFARS Appendix BB-304(i)) states:

> If a source selection has a mix of minimum mandatory requirements and essential characteristics or baseline requirements, most likely an initial competitive range will be determined on the basis of cost (price) and other factors that were stated in the solicitation and shall include all proposals that have a reasonable chance of being selected for award. The minimum mandatory portion need not be color rated; however, if it is, it shall be displayed as "green" for meeting the requirement or "red" for not meeting the minimum mandatory requirement. A narrative identifying the deficiencies is sufficient. The essential characteristics or baseline requirements are usually then evaluated and color rated. This minimizes the work of the technical team by not requiring them to evaluate the essential characteristics or baseline requirements for offerors which did not meet the minimum mandatory requirements.

However, not all source selections will utilize minimum mandatory requirements.

2.2.2.3.1.2 Symbols. Symbols may be used for ratings at the element level. For example, a plus (+) sign may indicate that the offeror has exceeded a standard; a check (√) may indicate that the offeror has met the standard; and a minus (-) sign may indicate that the standard has not been met for the evaluated element (AFFARS Appendix BB-304(e)).

2.2.2.3.1.3 Descriptive Adjectives. The AF assesses risk by assigning a risk rating, normally at the item summary level. Two types of risk assessed by the AF include Proposal Risk and Performance Risk (see definitions in next subsection). Table 4 provides a description of the risk ratings and their definitions.

In summary, any scoring method described in paragraph 2.2.2.2 could be utilized. The Air Force has implemented the color adjectival rating system as its standard method of evaluation (AFFARS Appendix BB-304). AFFARS BB-304(c) discourages the use of numerical weighting of evaluation criteria because of the difficulty to support small differences in technical merit when distinguishing differences in technical proposals (AFFARS BB-304 (c)).

Table 4

Definitions of Risk Ratings
(AFFARS Appendix BB)

RISK	DEFINITION
High	Likely to cause significant serious disruption of schedule, increase in cost, or degradation of performance even with special contractor emphasis and close government monitoring.
Moderate	Can potentially cause some disruption of schedule, increase in cost, or degradation of performance. However, special contractor emphasis and close government monitoring will probably be able to overcome difficulties.
Low	Has little potential to cause disruption of schedule, increase in cost, or degradation of performance. Normal contractor effort and normal government monitoring will probably be able to overcome difficulties.

2.2.2.3.2 Hierarchical Basis for Evaluation Criteria. The AF has broad discretion in determining the specific number and types of evaluation criteria it selects to use on any given acquisition. According to Comptroller General Decision B-186614, 76-2 CPD 235 (1976) in a legal case with Augmentation, Inc., "The determination of an agency's minimum needs and the selection and weights of evaluation criteria to be used to measure how well offerors will meet those needs are within the broad

discretion entrusted to agency procurement officials" (Cibinic and Nash, 1986: 541). Three common areas of evaluation include Technical Aspects, Cost/Price, and Past Performance. "Air Force source selection awards are based on an integrated assessment of each offeror's proposal using factors and subfactors which include: cost (price) criterion, specific criteria, assessment criteria, proposal risk, performance risk, and general considerations" (AFFARS Appendix BB-203(a)). Evaluation criteria consist of three types: specific criteria, cost (price) criterion, and assessment criteria (AFFARS Appendix BB-203(b)). The relative importance of the cost (price) criterion, specific criteria, and general considerations are stated in the solicitation (AFFARS Appendix BB-204(c)(5)).

2.2.2.3.2.1 Specific Criteria. The specific criteria relate to the particular program or requirements characteristics and what the offeror has proposed (AFFARS Appendix BB-203(2)). A list of key characteristics is developed that distinguish good performance from poor performance. This list includes the key discriminators forming the basis for all evaluation criteria. These criteria should include those things considered important to the customer about the specific requirement, such as quality of service, environmental considerations, and management (AFFARS Appendix BB-203). The specific criteria are typically divided into technical and/or management evaluation areas. Examples of specific criteria include major areas of performance, general facility maintenance, control of Government assets, and management (AFFARS Appendix BB-203(2)).

Specific criteria are segregated into tiering levels to facilitate the rating process. The hierarchical basis of the specific criteria described in the AF Supplement involves

establishment of Area, Factor, Subfactor and Element levels, listed in order of the most broad category to the most specific subcategory (AFFARS Appendix BB-304 and Cibinic and Nash, 1986: 541). The level of subdivision depends on the complexity of the area being evaluated. Factors are related to characteristics which are important to successful contract performance. According to AFFARS Appendix BB-304(b):

> Color ratings are mandatory at the factor and subfactor level. Colors may also be used at the element level, although symbols may be used as an alternative at these lower levels. The color rating depicts how well each offeror meets the evaluation standards. Color ratings are not summarized above the factor level. However, if the SSA requires a summary rating at the area level in the SSP, color ratings shall be used. To provide for a standard color scheme, the spectrum (in Table 1) shall be used. Ratings must be accompanied by a consistent narrative assessment (inclusive of strengths and weaknesses) of the basis for the rating. The definitions stated below shall be followed any time color ratings are used. Deviations from these definitions can only be obtained by forwarding a request through SAF/AQCP.

If an offeror's proposal is evaluated as unacceptable or "red" at any level of the evaluation criteria, this event is recorded in the rating and narrative assessment at that level and at each higher level in the evaluation process. This record ensures that deficiencies discovered at the lower levels are reported to the highest rated level (AFFARS Appendix BB-304(e)).

According to AFFARS Appendix BB-205(a), an offeror's proposal shall not be compared against a competitors. Selected "minimum standards," determined as required to meet the evaluation criteria, set an objective standard which becomes the baseline of measurement on how well each offeror's proposal satisfies the evaluation criteria. The standards may be qualitative, quantitative, or both; and currently do not appear in either the Source Selection Plan or the solicitation (AFFARS Appendix BB-205(a)). The

criteria and standards selected for evaluation are directly linked to the areas of performance required for successful completion of the task, are not so restrictive as to discriminate against competing offerors, and are mutually exclusive of other criteria to avoid double evaluating an offerors' proposal for the same strengths or weaknesses (Cibinic and Nash, 1986).

2.2.2.3.2.2 Assessment Criteria. The assessment criteria serve as a basis for evaluating each offeror's proposal as it relates to the relevant evaluation criteria. It pertains to how the contractor will perform the effort or satisfy the requirement. Assessment criteria are used in conjunction with evaluation standards to judge how well an offeror's proposal satisfies each of the relevant evaluation criteria. Factors and subfactors are created to support those criteria. Examples of common assessment criteria include soundness of the proposed approach, and how well the offeror understands and complies with the requirement (AFFARS Appendix BB-203(b)(3)). Assessment criteria are also ranked in relative order of importance or identified as of equal importance (AFFARS Appendix BB-204(c)(5)).

2.2.2.3.2.3 Integrated Evaluation Matrix. Table 5 provides an example of an Evaluation Matrix for one specific Technical Area. This table illustrates an example of the relationship between specific criteria, assessment criteria, and the color and risk ratings assigned by the source selection evaluation team.

2.2.2.3.2.4 Cost (Price) Criterion. The cost (price) criterion relates to the evaluation of the offeror's proposed costs or price. Cost (price) is a mandatory evaluation criterion used to evaluate every AFFARS Appendix AA/BB

source selection for realism, completeness, and reasonableness. Color ratings or proposal risks are not applied to the evaluation of cost (price) (AFFARS Appendix BB-203(b)(1)).

Table 5

Evaluation Matrix for Technical Area (Example)
(AFFARS Appendix BB, Attachment BB-3)

AREA: TECHNICAL			
ITEM SUMMARY	Green (Low)	Yellow (Moderate)	Red (High)
	ITEM	ITEM	ITEM
SPECIFIC CRITERIA	Reliability, Maintainability, and Producibility	Systems Engineering and Integration	Weapon Control Systems Design
ASSESSMENT CRITERIA			
Soundness of Approach	Green	Yellow	Red
Understanding of Requirement	Green	Yellow	Yellow
Compliance with Requirement	Green	Green	Green

2.2.2.3.2.5 ***General Considerations.*** General considerations relate to proposed contractual terms and conditions, results of preaward surveys, and other surveys or reviews (AFFARS Appendix BB-203(c)). Examples of items of general consideration include financial capability assessments, production

readiness reviews, and preaward surveys. General considerations are not evaluated using color coding, but are considered in the integrated assessment of the overall proposal.

2.2.2.3.2.6 ***Proposal Risks.*** Proposal risks are assessments associated with schedule and performance or technical aspects of the program (AFFARS Appendix BB-203(c)). Proposal risks are not evaluated using color coding.

2.2.2.3.2.7 ***Performance Risks.*** Performance risks relate to cost and specific criteria. Performance risk is assessed for each area or as an overall general assessment of performance (AFFARS Appendix BB-203(e)). Performance risks are not evaluated using color coding.

2.3 Flow of Information into the Source Selection Process

Proposal evaluation is an assessment of the proposal and the offeror's ability to perform the prospective contract successfully (FAR 15.305(a)). To properly evaluate each proposal, the source selection officials need four main types of information: technical, cost/price, advisory, and contractor past performance. A technical evaluation is an assessment of each offeror's ability to accomplish the technical requirements. The technical team reviews the proposals, and based upon their expert knowledge, assesses each offeror's ability to successfully perform the task given the offeror's proposed technical and/or managerial approach to solve the problem. A cost/price evaluation is an assessment of the proposed cost/price for realism and reasonableness in relation to the technical approach proposed. The proposed cost/price is also compared with a Government estimate of the work to be performed. Expert advisory information is needed by the source selection team in areas such as legal advice; contracting and business policy

advice, i.e. latest policy issues, pre-award surveys, equal employment opportunity compliance reports, and small business subcontracting efforts; and sometimes additional expert advice is required in technical, cost, and past performance areas. Past performance information is another indicator of an offeror's ability to perform the contract successfully. An assessment is made to determine the risk associated with the contractor's past work history as it relates to the current acquisition. Current and relevant information from reliable sources is necessary to evaluate the general trends of a contractor's performance within the context of the acquisition. Figure 1 depicts a model of the types of information required by the SSAs for decision-making during a source selection.

2.3.1 Prior Research on the Automation of Information into the Source Selection Process.

2.3.1.1 Evaluation Criteria (Technical/Cost/Past Performance). In a 1991 AFIT thesis, Ken Noffsinger examined the evaluation criteria used in source selections at the Air Force Logistics Command. Noffsinger examined contracting files at the Wright-Patterson Contracting Center and Warner-Robins Air Logistics Center to determine the types of evaluation criteria used in the source selection process and to assess their usefulness in making source selection decisions. Thirty-two source selections awarded between the years of 1986 through 1991 were evaluated (Noffsinger, 1991: 41, 47). Noffsinger developed a "frequency count database" to analyze the most frequently used evaluation elements identified as criteria in the categories of General Considerations, Assessment Criteria, and Specific Criteria (Noffsinger, 1991: 48-50). He used these elements as the basis for analysis of their relationship to the award decision. He organized the data into twelve categories: cost ranking, overall technical color rating, overall

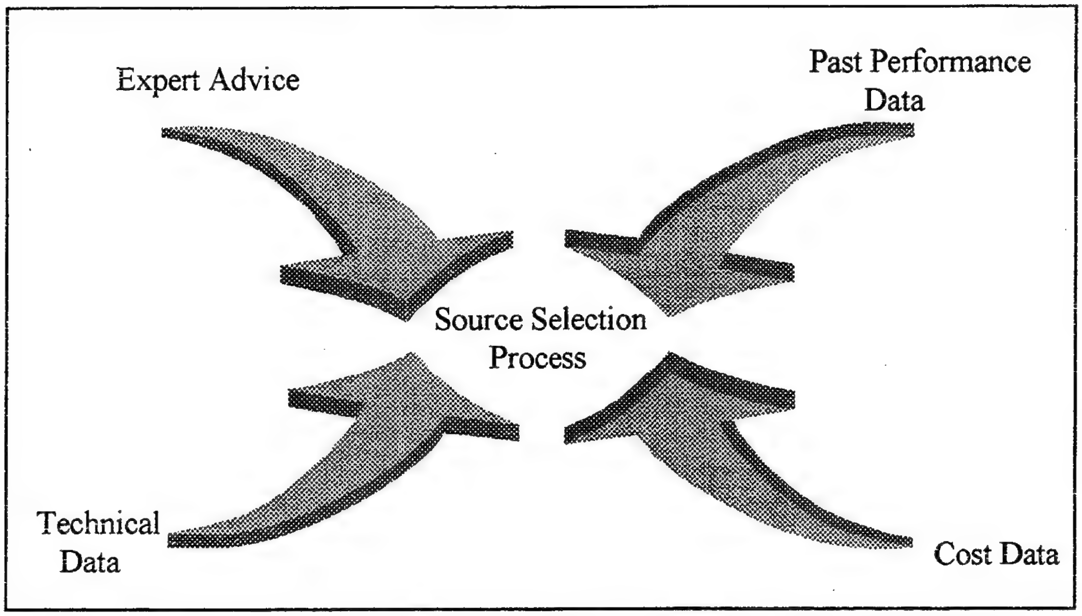

Figure 1. A Model of Information Needed to Make an Optimal Decision.

technical risk rating, overall technical color/risk rating, other area color rating, other area risk rating, and other area color/risk rating, past performance risk rating, cost risk rating, financial risk rating, schedule risk rating, and contractual risk rating (Noffsinger, 1991: 51-52). He recommended continuation of this research, including an extension into "an examination of the degree to which evaluation criteria contribute to the selection of satisfactorily performing offerors, which substantially meet all of the terms and conditions of the contract for the duration of the contract" (Noffsinger, 1991: 82). He suggested statistical techniques, such as discriminate analysis or categorical modeling, to identify evaluation criteria to select a high performing contractor. This research has not been accomplished. To collect the amount of contracting information required to obtain significant results for this research would be difficult because contract files are located in various locations, and manual collection through requesting copies of solicitations and contractor performance data would be cumbersome. Done manually, this research would

be almost impossible due to time constraints and the magnitude of information. Use of information technology, such as a database or data warehousing system for data collection and storage, and the inclusion of statistical software for analysis, make this continued study feasible and its potential expansion into operational capability promising. A search to obtain the information stored in a computer would permit the researcher to gather data for analysis. With increased emphasis in awarding to contractors who have a good performance record, this operational capability could substantially benefit the AF with the resulting analysis.

2.3.1.2 Past Performance. In a 1989 AFIT thesis, Major Paul Thurston attempted to "establish the requirements baseline and conceptual design for an automated information system, based upon the Contractor Performance Assessment Reporting System (CPARS), in order to collect, process, protect, and disseminate contractor performance assessments" (Thurston, 1989: 1-8). In essence, he attempted to design a database system which could be used during source selections to obtain information regarding contractor performance risk. He describes in detail what information the database should include, and how it should be sorted for easy manipulation and review of the data. A prototype software model was developed but was never implemented for use.

2.3.1.3 Expert Advice. In another 1989 AFIT thesis, Major Caisson Vickery used a computer-aided decision support system (DSS) in the source selection process. A decision support system (DSS) is, in loose terms, an "information system" specifically designed to assist with decision-making. According to Gordon and Gordon, a DSS enhances decision-making by providing information necessary to effectively answer

complex questions. The DSS is designed to evaluate the impact of alternative decisions in making the best possible, or optimal, choice. The system is designed to integrate both internal and external information from sources for incorporation into models and analytical tools (Gordon and Gordon, 1995). In his research, Major Vickery used a DSS based upon an analytical hierarchy process, and which utilized the "Expert Choice" software program. Vickery stated a DSS using an analytical hierarchy process aligned real-world decision-making due to the hierarchical structure of the source selection criteria into area, item, and factor and subfactor levels. Using both a test group and a control group for experimentation, Vickery tested the DSS for effectiveness, consistency, speed, difficulty, confidence, and understanding. According to the results of his experiment, the DSS had little effect on effectiveness and consistency, a negative impact on speed, and a positive impact on ease, confidence, and understanding (Vickery, 1989). The negative impact on speed could have been due to participant unfamiliarity with computers or the DSS. "The extent to decision effectiveness depends on the user's familiarity and expertise with the decision support tool, the user's knowledge about the problem to be solved, and the interaction of the cognitive style of the user with the DSS" (Gordon and Gordon, 1995: 331).

2.4 Information Technology Overview

According to Steve and Judith Gordon, in Information Systems, A Management Approach, the components of information technology consist of "computer software, hardware, database management systems, and data communication systems" (Gordon and Gordon, 1995: 13). Gordon and Gordon identify four types of information systems:

automated systems, transaction processing systems, management information systems, and strategic systems. Automated information systems (AIS) are those systems that use information technology to perform tasks that would otherwise be accomplished manually. An Expert System (ES) is a type of AIS automating the knowledge of expert in a particular field. A transaction processing system (TPS) records and processes an organization's routine business activities. Management information systems (MIS) are designed to supply the information an organizational manager requires to function better or to communicate more effectively. MIS systems include management reporting systems, decision support systems (DSS), and executive support systems (ESS) or executive information systems (EIS). Strategic systems extend a systems concept beyond organizational boundaries, seeking to make customers, suppliers, or distributors a strategic partner of the information system (Gordon and Gordon, 1995: 15-16). "A Database Management system (DBMS) contains software comprising of programs to store, retrieve, and otherwise manage a computerized database and provides interfaces to application programs and to nonprogramming users, as well as a host of other data creation, manipulation, and security features" (Gordon and Gordon, 1995: GL-6). This study concentrates on the use of a shared DBMS data warehousing system, an MIS decision support system, and an AIS expert system.

2.4.1 Data Warehousing. The DoD Standard Procurement System (SPS) is implementing the use of shared data warehouses and relational databases in its system's integration design. Shared data warehouses store information which can be simultaneously accessed by personnel at various locations. The SPS will contain a

database to store audits of defense contractors conducted by the Defense Contract Audit Agency accessible by contract specialists. The SPS will also have a database to conduct price analysis using historical data on purchases of the same product (DoD SPS, 1998). Shared data warehouses provide the basis for obtaining data to conduct statistical analysis and other evaluations useful in the decision-making process. A relational database model provides a logical connection between data objects, or entities, and internally organizes the data in a way that makes retrieval of information quick and efficient. The use of a relational database management system supports decision support and ad hoc query applications (Gordon and Gordon, 1995: 200-201).

A CPARs database has recently been implemented by the Headquarters Air Force Material Command (HQ AFMC) to collect, process, and store contractor past performance information within HQ AFMC organizations. The development of this database will provide past performance information to SSAs. However, this database is limited in scope as it contains only CPARS data on contracts awarded and administered within HQ AFMC organizations. Expanding the use of information technology, such as converting to a data warehousing system for data collection and storage, could provide more Government users access and storage of information regarding the performance of contractors whose contracts are administered by other AF and Government agencies. "A data warehouse supports business analysis and decision-making by creating an integrated database of consistent, subject-oriented, historical information. It integrates data from multiple, incompatible systems into one consolidated database. By transforming data into

meaningful information, a data warehouse allows business managers to perform more substantive, accurate and consistent analysis" (Prismsolutions, 1998).

> Significant cost benefits, time savings and productivity gains are associated with using a data warehouse for information processing. First, data can be easily accessed and analyzed without time-consuming manipulation and processing. Decisions can be made more quickly and with confidence that the data is both timely and accurate. Integrated information can be kept in categories that are meaningful to profitable operation. Trends can be analyzed and predicted with the availability of historical data. [Data warehousing] assures that everyone is using the same data at the same level of extraction, which eliminates conflicting analytical results and arguments over the source and quality of data used for analysis. In short, the data warehouse enables information processing to be done in a credible, efficient manner. (Prismsolutions, 1998)

Since most defense contractors contract with more than a single Government agency, the past performance information included in an all-encompassing data warehouse would more closely reflect the contractor's complete performance position and provide the SSA with a more accurate assessment of the contractor's ability to perform. A past performance data warehouse system could be maintained at a central location, with interfaces to each Government agency, to provide more efficient maintenance and security of the information contained within the data warehouse. The inclusion of On-line Analytical Processing (OLAP) statistical or analytical software within the system, or through the use of an interface with a DSS or Expert system, could provide for analysis of performance risk based upon the information and provide SSAs with both a detailed and summary report of the analysis. Use of OLAP, in conjunction with a data warehouse, could provide SSAs with a probability factor for the prediction of contractor success or failure based upon its current and relevant past performance history (Gordon and Gordon, 1995).

2.4.2 Decision Support System. A DSS is specifically designed to enhance decision-making by helping managers answer complex questions. Most DSSs are designed to assist with strategic or managerial level questions, however a well designed DSS system can be used at any level (Laudon and Laudon, 1995). A DSS provides information required for effective planning and organizing. DSSs are designed to allow for effective decision-making in ambiguous and complex environments. They provide managers with the ability to quantitatively analyze alternative choices by modeling a complex set of circumstances which the decision maker can manipulate. By manipulating the various parameters of the model, the manager can assess the impact of diverse conditions related to each alternative solution to make a better decision (Gordon and Gordon, 1995: 330-331).

According to Marakas and Elam, a user's decisions can be influenced by a DSS, and software which is designed to assist decision-making allows more creativity in developing possible alternate solutions (Marakas and Elam, 1997). A strategically designed DSS could be useful in assisting a source selection team in the development and evaluation of the source selection criteria for award decisions. A DSS could assist in the planning and selection of the specific evaluation criteria required by evaluators to choose the best value alternative, and also during the evaluation process, by allowing them to examine possible evaluation scenarios using "what if" questions, obtaining expert advice, and searching rules and regulations for conflicts and problems. "Planned systems can handle unforeseen questions by providing access to internal and external data and models to manipulate the data" (Gordon and Gordon, 1995: 332).

*2.4.2.1 **DSS Components***. The major components of a DSS include a database, a knowledge base, a model base, and a user interface. The database provides access to internal and external data pertinent to decision-making. "DSSs use historical data from the database to form the baseline that mathematical models use in extrapolating from past to present to future conditions" (Gordon and Gordon, 1995: 331). A knowledge base, like that of an expert system, consists of rules that constrain possible solutions as well as alternative solutions and methods for evaluating them. The knowledge base provides information about data relationships that are too complex for a database to delineate. A model base includes an array of spreadsheets, simulation packages, forecasting tools, and statistical packages. The model base allows the user to access the appropriate tools without developing a new model each time. A user interface allows the user to control which data and models to include in the analysis. A DSS must be designed to support the increased flexibility users have in manipulating data and processing information. Since DSSs support complex decision-making, users generally analyze many alternatives and extensive data about each alternative. A DSS should be designed to support the manipulation of data using a broad range of graphical and tabular forms (Gordon and Gordon, 1995: 331-332).

*2.4.2.2. **DSS Benefits***. Benefits of the DSS include improved decision-making through a better understanding of the business situation, an increase in the number of decision alternatives that can be examined, the ability to implement ad hoc analysis, and faster response to expected situations. DSSs also improve communication, effective teamwork, and time and cost savings (Gordon and Gordon, 1995: 330-331).

2.4.2.3 DSS Business Applications. Wong and Monaco conducted research on specific business applications, to determine the functional focus of DSS design in planning and monitoring systems. The focus on interpretation and prediction-type systems, the type required for competitive source selection decisions, indicates most of the design and development is centered in the operations/production, finance, and information systems functions (Wong and Monaco, 1995). Little research has been focused on the design and development of a DSS system specifically for competitive procurements which could assist the decision-maker in determining the best source. Several systems have been developed to assist commercial procurement specialists during negotiations, but in Government Contracting, negotiations occur in sole source procurements rather than competitive acquisitions.

Heng Li (1996) used a combination ES and DSS database, which used case-based reasoning (CBR) to allow negotiators to access and draw on actual case history during the negotiation process. Although Heng Li doesn't specifically acknowledge the system as a link between using an expert system (MEDIATOR) and a DSS database, he did integrate the technologies to providing a system which could draw on past experience in the form of a case-based reasoning database to find similarities in past negotiations. By drawing on historical cases, rather than expert opinion, this integrated system acted as a neutral, third party mediator to prevent "deadlocks" in current negotiations. During system development, problems were encountered in collecting previous negotiation cases to include in the database. Direct collection was difficult because negotiation history was seldom recorded and documented. Also, determination of the original context of a

negotiation was often difficult to establish when finding similar cases, as all circumstances may not be the same (Li, 1996). One draw-back to the use of case-based reasoning, that is not discussed by Li, is the use of historical data tends to set a precedence for similar decisions even though circumstances may not be the same as in the original case, or even when the initial decision was in error.

Rangaswamy and Shell (1997) used a "Negotiation Support System" called NEGOTIATION ASSISTANT (NA) designed to enable negotiators to analyze their own preferences and to provide a structured negotiation process in assisting parties in negotiating optimal trade-offs. The model was based on a multiattribute representation of preferences with communications occurring over a computer network. The parties sent and received offers and counteroffers via the system. The NA assisted negotiators in reaching a mutual agreement, and then analyzed the final agreement to see if either party could benefit from a more compromising, Pareto-optimal solution. The results of their experiment suggest parties using the negotiation support system in structured negotiation settings achieved better outcomes than parties negotiating face-to-face or via e-mail (Rangaswamy and Shell, 1997).

Liberatore and Stylianou (1994) developed a system for the design, development, and implementation of a knowledge-based decision support system (KBDSS) for strategic market assessment which could possibly be modified for use in source selection decision-making. The resulting system, known as the Strategic Market Assessment System (SMAS) integrated a "knowledge-based system with scoring models, logic tables, and an analytic hierarchy process to evaluate whether a product should be selected for full-scale

development" (Liberatore and Stylianou, 1994). The analytical hierarchy process (AHP) provides a more structured approach for determining the scores and weights for multi-criteria scoring models. Multi-criteria scoring models score or rate each alternative in a decision problem based on each criterion (Ragsdale, 1997: 716). According to Liberatore and Stylianou, the AHP is a decision-making method for prioritizing alternatives when multiple criteria must be considered. It allows the evaluator to structure a problem into levels such as: the goal, the criteria, the ratings scale, and the projects themselves. The hierarchy analyzes the impact of any level on the next higher level. The process begins by determining the relative importance of the criteria in meeting the goal and their relative weights. The AHP-scoring approach forms the basis of a decision support system for project evaluation. A knowledge-based system, like ES, encapsulate, model, and process the knowledge of experts. In conclusion of the field test, Liberatore and Stylianou state the KBDSS is an appropriate modeling framework for new product development (Liberatore and Stylianou, 1994).

In the late 1980s, the U. S. Department of Housing and Urban Development developed a decision support system that serves headquarters and field offices for the Urban Development Action Grant Program. The DSS supports the operations and work processes of the program office as well as managerial decision-making regarding grant applications. The DSS includes "quantitative analysis techniques and tools, management decision-making support, 'what-if' capability, direct and intermediary control by the decision maker, support to nonprogrammable decisions, real-time analysis capability, and contingency planning features" (Gordon and Gordon, 1995: 332).

2.4.2.4 ***DSS and Time Pressure in Source Selections***. In the acquisition field, the need to process large amounts of information in a relatively short time has an impact on decision strategy and performance. The standard time for completion of a source selection is 120 days. The goal of AF Lightning Bolt #10 is to reduce acquisition cycle time by 50%. Cycle time is measured from the receipt of a validated user requirement/funding commitment to contract award (SAF/AQXA, 1997). If a difficult acquisition requires more time to complete, but the time standard is inflexible, the shorter time available for processing would increase task difficulty for the evaluation team. The more difficult task may cause the selection of a suboptimal strategy or alternative, which in the case of a source selection, could result in reduced performance, schedule impacts, and increased costs. According to Hwang (1994), a DSS can be used to counterbalance the negative impacts time pressure has on decision strategy selection and performance. A theoretical graph of performance as a function of time pressure is an inverted U-shape (Figure 2).

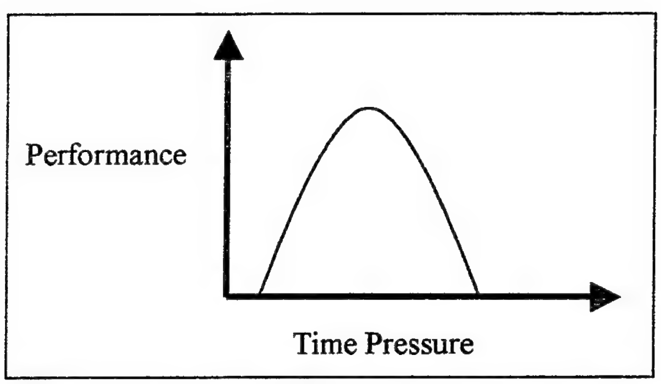

Figure 2. U-Shaped Effect of Time Pressure on Performance (Hwang, 1994).

Time pressure improves decision performance to a point after which additional time pressure decreases performance. "The basic assumption of cognitive fit is that

humans have limited information processing capability and so [they] try to reduce the task complexity in solving problems" (Hwang, 1994: 201). Information systems designed to enhance decision-making have an important role in supporting decision-making under time pressure (Hwang, 1994). These information systems have information processing capacity that will not decrease due to an increase in task difficulty or time pressure so a more extensive analysis of alternative solutions is feasible. This could lead to the selection of better solutions, reduce error due to fatigue, save time and money, and prevent schedule delays.

2.4.3 Expert Systems. "Expert systems (ES) are computer programs designed to make available to users the knowledge of experts in a particular field" (Dilworth, 1993: 614). In his 1995 AFIT thesis, Shawn Northrup states ES's have emerged as one of the leading mechanisms for providing...optimal answers, and have become one of the user's most valued tools" (Northrup, 1995). A definition by Feigenbaum states "an Expert System…is an intelligent computer program that uses knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise for their solution" (Northrup, 1995). ES's generally automate the role of an expert in a given field, and because they help people make decisions, they are tools for decision support (Gordon and Gordon, 1995: 283).

2.4.3.1 Expert System Components. The basic core of an ES contains an inference engine and a knowledge base, or database. A natural language interface permits the system to communicate with the user. The system's knowledge base consists of traditional knowledge, or facts and other information, and "if then" rules to determine how

the data relate to other data and to potential solutions. These inference rules are rules of good judgment and reasoning that characterize expert-level decision-making and problem solving. These rules are established by interviewing experts in the field to determine how they make decisions (Dilworth, 1993: 614).

The inference engine, or control mechanism, does the actual problem solving. It contains programs that allow the system to evaluate the rules in the knowledge base. The inference engine determines which rules to invoke, depending upon what has already been determined about the problem. The inference engine is separate from the knowledge base, so a single inference engine can be used to drive several knowledge bases. This separation creates expert "shells" which can accommodate a wide range of disciplines, depending on the data loaded on each knowledge base (Dilworth, 1993: 614). ES shells use an interface engine to process the language statements and data supplied by users to reach conclusions, answer questions, and give advice. Figure 3 is a simple illustration of a short program containing two facts and one rule which may be expressed in the language of an expert system shell. An inference engine would use this program to determine whether or not Mary is Alan's aunt by analyzing and comparing the "Rules" knowledge base with the "Facts" knowledge base to provide an answer (Gordon and Gordon, 1995: 134).

2.4.3.2 Expert Systems and Artificial Intelligence. The knowledge base is the heart of the expert system. The first knowledge bases used "if-then" type rules but these rules became inefficient because the knowledge bases grew so enormous and complex it made inferencing impossible. Later, an approach called Bayesian Knowledge Base (BKB) was used to overcome incompleteness and provide more flexibility as it can

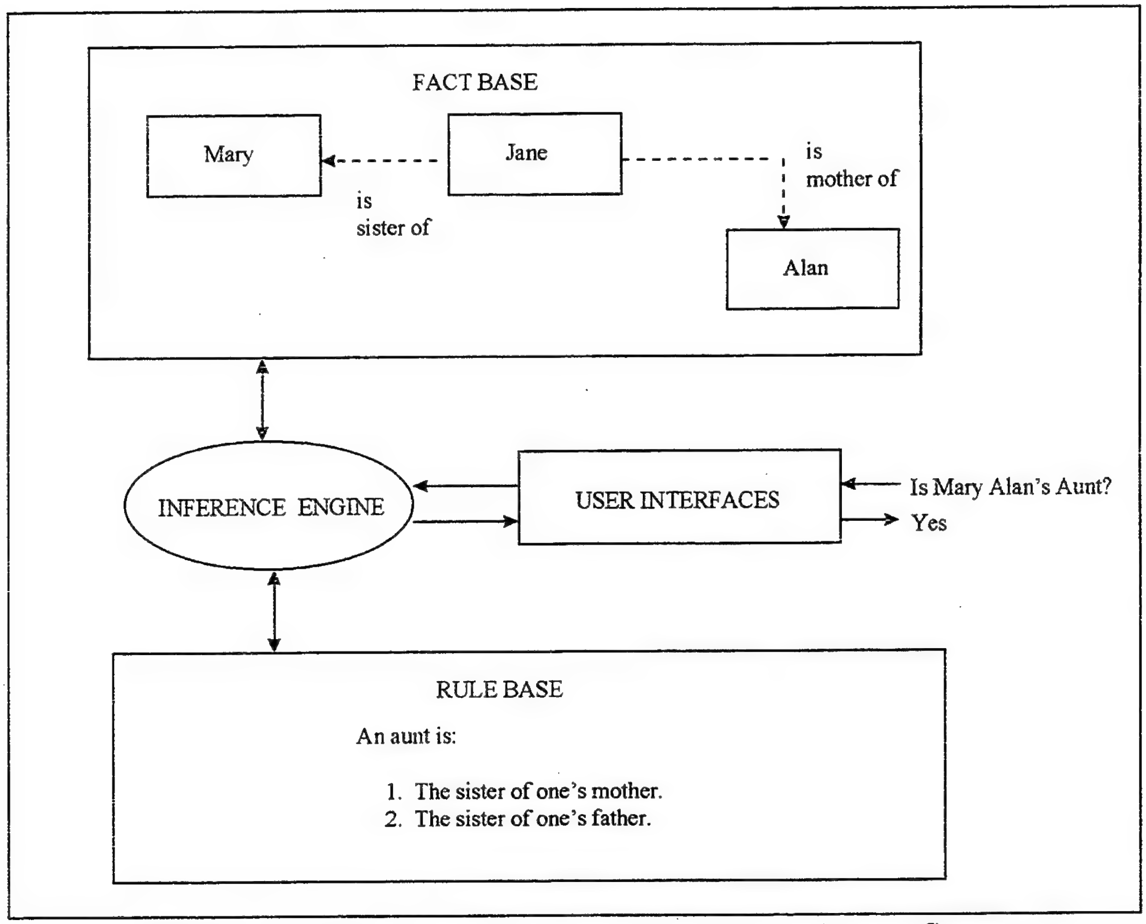

Figure 3. An Illustration of Rules and Facts for an Expert System (Gordon and Gordon, 1995: 134).

represent a type of cyclic knowledge and can inference using incomplete probability tables (Northrup, 1995). More recent systems operate using Artificial Intelligence (AI). AI is a "branch of computer science that attempts to give computers the ability to understand language, to solve problems that call for reasoning, and to learn—in sum, to emulate human methods of learning and solving problems" (Dilworth, 1993: 613). ES's are the most widely used operation to employ AI. AI approximates human reasoning through the manipulation of symbols (i.e., Rule Base in Figure 2), as opposed to conventional systems which manipulate numbers and use algorithms to solve problems. Conventional systems process data and make mathematical calculations quicker than the human brain, and they

do not become fatigued by repetitious tasks. For this reason, conventional computers can be considered better than humans at many tasks. However, for tasks that require creativity or new rules and insights, conventional systems may not be as successful as humans. The ability to use incomplete data for analysis makes AI systems more flexible than conventional systems. AI systems "make assumptions," and simulate inductive reasoning by comparing incomplete data to idea models" (Dilworth, 1993: 613). Systems that use both simulated inductive reasoning and conventional standards with set algorithms resemble the intuitive and logical thought processes that humans use to solve problems. AI systems are good at orderly thought. With the use of artificial intelligence, expert systems can offer advice. Expert systems can also act as interpreters to enhance communications between various automated systems (Dilworth, 1993: 613-614). Integration of an expert system with one or more components of a DSS allows the ES to act as a consultant to the DSS. Stand-alone ES's are limited in their strategic decision-making ability. Integration of an ES into a decision support system makes the decision maker better equipped to handle broad, ad hoc, or unique problems than if using a stand-alone expert system. Using a system based on ES/DSS integration could improve a decision-maker's performance in a strategic planning environment by helping identify problems and providing relevant theoretical models (Wong, 1995).

2.4.4 Microsoft Excel SOLVER as Model Base. The Air Force competitive source selection process is based upon a hierarchical evaluation system (paragraph 2.2.2.3.2) to determine award of the proposed alternative that represents the best value to the government. An alternative is "a course of action intended to solve a problem"

(Ragsdale, 1997: 671). Air Force source selections are based on factors other than price alone to determine who receives contract award. Due to this, both quantitative and qualitative data flows into the source selection process and must be evaluated and analyzed in comparison to the evaluation criteria and standards provided in the source selection plan for each individual acquisition. A DSS model base can assist the source selection team in their manipulation and analysis of the information flowing into the decision process.

"Management Science [(or Operations Research)] is the field of study which uses computers, statistics, and mathematics to solve business problems" (Ragsdale, 1997: 1). As stated in paragraph 2.4.2.1, a model base includes an array of spreadsheets, simulation packages, forecasting tools, and statistical packages. The model base allows the user to access the appropriate tools without developing a new model each time. The Microsoft Excel program is a management science tool which has the capability to perform mathematical optimization using linear, integer linear, and nonlinear programming techniques. It also includes goal programming and multiple objective optimization features. It has the capacity to perform simple and multiple regression analysis, discriminant analysis, and time series analysis. It can analyze risk through the use of simulation techniques. It also features queuing theory, project management, and decision analysis techniques (Ragsdale, 1997). These features can be used in conjunction with the graphics, charts, and other features contained in the Windows 95 or Window 97 software packages (Excel spreadsheet programs, Access database, Powerpoint graphics, Word for

text) to analyze and present a consolidated evaluation briefing to the SSA for final decision selection.

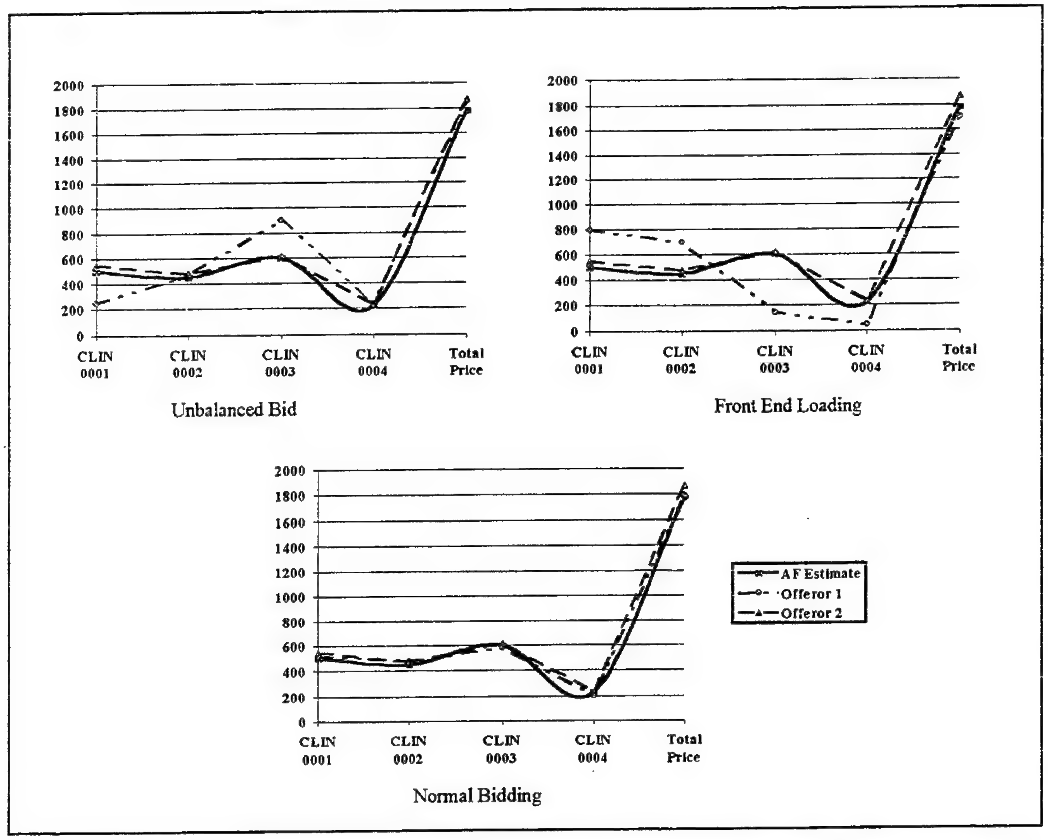

Figure 4. Line Graph Evaluation Comparison of Normal vs. Deviated Bids.

One example of using an Excel spreadsheet, in conjunction with graphics, which could assist the SSA to visually examine the existence of offeror front end loading or unbalanced bids is through the use of line graphs. The SSA could graphically compare each offeror's line item costs to the Government estimate and look for visual deviations of extremely high or low proposed costs per line item (Figure 4). As can be seen in Figure 4, under normal bidding, all offerors proposed costs and the Government estimate are comparable with only minor deviations between proposed costs and the Government estimate (assuming the Government estimate is a good estimate). An offeror may

sometimes see an opportunity to front load the costs of the items to be delivered first, in order to be paid in advance of incurring the costs of the latter delivered items. In Figure 4, Offeror 1 has front loaded the costs of contract line item numbers (CLINs) 0001 and 0002 and reduced the costs of the CLIN to be delivered at a later date. If the award was to be made to the lowest priced bid, evaluation of total price alone would have awarded the contract to Offeror 1. If CLINs 0003 and 0004 were Option CLINs, which may or may not be exercised, Offeror 1 may not be the lowest priced offeror, even though his offered price is the lowest total price proposed. In unbalanced bidding, Offeror 1 has proposed an extremely low cost for CLIN 0001 but an extremely high cost for CLIN 0003. Unbalanced bidding is usually due to a perceived Government emphasis on specific evaluation criteria in the solicitation, or on a perceived quantity of items the offeror estimates will be desired by the Government per specific CLIN. This normally happens in an Indefinite Delivery, Indefinite Quantity (IDIQ) or Requirements type contract, where the offeror attempts to lower his costs on items which he estimates the Government desires, and raises the price on the items he estimates the Government requires. Manual evaluation of proposals for front end loading or unbalanced bids is tedious and time-consuming for the contracting official, especially as the number of offerors and the number of contract line items increase. By placing the offerors proposed prices in a spreadsheet, and graphically displaying the costs per CLIN, the contracting official need only look for abnormalities that deviate from the Government estimate and competing offerors proposed prices. Once the evaluation team is properly trained in using these techniques, evaluation

time should be reduced as the computer can strategically manipulate the data and analyze it faster, with more accuracy than manual calculations.

2.4.4.1 The Management Science Approach to Decision-Making. Management science (or operations research) "involves applying the methods and tools of science to management and decision-making" (Ragsdale, 1997: 1). In the past, management science was a specialized field which required practitioners to have a mainframe computer and an advanced knowledge of mathematics and computer programming languages to manipulate data (Ragsdale, 1997: 3). The concept of using management science models in problem solving and decision analysis is not new. Both Vickery (1989) and Noffsinger (1991) discuss the use of the Analytical Hierarchical Process (AHP) as a potential model for decision-making in the Government source selection process. Vickery's study on the use of Decision Support Systems suggests the use of an AHP approach developed by Saaty in 1982, as the proposed method of ranking in source selection decision-making (Vickery, 1989). Noffsinger's study on the relationship evaluation criteria has on the award decision discusses commercial purchasing practices implementing AHP as the "method by which purchasing managers may attack the supplier selection problem" (Noffsinger, 1991: 35). However, the costs and complexity of past technology limited the use of management science tools in the business world. The emergence of personal computers (PCs) and the development of easy-to-use spreadsheets have made these tools more practical and available for use in business decision-making (Ragsdale, 1997: 3). Use of these tools in the design and development of Information Systems for business applications and decision-making is a means to change a

"tactical" information systems design into a more "strategic" system design. A statement from CIO, Mr. Ron J. Ponder, at Sprint Corporation (and former CIO at Federal Express Corp.) emphasizes:

> If IS [information system] departments had more participation from operations research analysts, they would be building much better, richer IS solutions... Ponders and others say analyst trained in operations research or management science can turn ordinary information systems into money-saving decision-support systems and are ideally suited to be members of the business process re-engineering team (Ragsdale, 1997: 11).

2.4.4.2 Mathematical Programming or Optimization. Mathematical programming (MP), or optimization, is "a field of management science that finds the optimal, or most efficient, way of using limited resources to achieve the objectives of an individual or business" (Ragsdale, 1997: 16). Some business applications implementing MP techniques in decision-making include the determination of product mix to maximize profits or to satisfy demand at a minimum cost, the routing and logistics of merchandise to stores to minimize transfer costs, and in financial planning the minimization of the amount of taxes paid while staying within the constraints of the tax laws (Ragsdale, 1997: 17).

Vickery discusses optimization as making "the best possible decision under the circumstances at hand" (Vickery, 1989: 11). His research studied various opinions on optimizing, satisficing, and decision-making, including Simon, 1976; Janis and Mann, 1977; Lohaus, 1985; and Cook, 1987. Simon's approach for finding the optimal solution was like a rational man who makes decisions based upon perfect knowledge of all alternatives, and who examines the alternatives using an economic cost-benefit analysis. Lohaus's approach was like a decision-maker who "considers all possible solutions by

weighing the alternatives against each other until the best or optimal solution is found." Lohaus further describes the process of "satisficing," rather than "optimizing," to find a solution that is "good enough." Satisficing involves identifying, testing, and gaining acceptance of an "acceptable" solution due to the human minds limitations to optimize. Janis and Mann had previously categorized obstacles to optimization as limitations of the mind or bureaucratic obstacles. Satisficing is evident in Cook's research. Cook found that "only 45.5% of managers optimize" (Vickery, 1989: 11-14). Vickery's research demonstrates the need to use information technology when examining alternatives to assist the "human mind" to optimize in decision-making rather than to select an acceptable solution and satisficing. An information system with the proper decision-making tools can analyze iterations of information without interference from human constraints, such as tediousness, fatigue, or boredom.

2.4.4.3 Optimization Tools. An optimization model can be written using several different tools: a spreadsheet, a modeling language, or a solver library for custom programs. The spreadsheet is the basic optimization tool. Modeling languages, such as algebraic modeling languages, are written at a higher level language than spreadsheet tools. These modeling languages are designed to be more flexible than spreadsheets as the amount of data used in the model, or dimensions, begin to change. Solver libraries for customs programs are created to increase efficiency of a model or specific solver by capitalizing on special features. These libraries provide special translation codes to allow the solver to run numerous variations of an optimization model simultaneously and at a

faster speed (Compass, 1998). A system using the solver library translation codes could permit evaluations of award by several contracting officials simultaneously.

The spreadsheet approach was chosen for analysis in this study due to its commercial availability and easy accessibility to Government contracting and source selection personnel. Spreadsheets, such as Microsoft Excel, are becoming increasingly important for "prototyping and building mathematical programming-based decision-support models" (Compass, 1998). Spreadsheets can be used to create, modify, format, and audit the model, and as demonstrated in paragraph 2.4.4, it is easy to add charts and graphics for presentations. Spreadsheets are "inherently free-form and impose no particular structure on the way we model problems" (Ragsdale, 1997). Once personnel become accustomed to Excel spreadsheet modeling, the learning curve for model development is reduced. In addition, communication of results to management and other personnel is facilitated because of a general familiarity of spreadsheet programs (Compass, 1998). "Microsoft Excel's SOLVER provides one of the most effective ways to manipulate LP models in a spreadsheet" (Ragsdale, 1997: 109).

2.4.4.4 Optimization Models Expressed Mathematically. An optimization model generates a "best solution" based on a set of constraints (Vickery, 1989: 16). The three elements of an optimization problem are decisions, constraints (or restrictions), and an objective (or goal) (Ragsdale, 1997: 17-18). Optimization problems can be expressed mathematically using these three elements. Decisions, or decision variables, are represented by symbols such as $X_1, X_2, \ldots, X_n$. The constraints can be represented in a variety of forms. Three general ways of stating possible constraints are:

A less than or equal to constraint: $f(X_1, X_2, \ldots, X_n) \leq b$
A greater than or equal to constraint: $f(X_1, X_2, \ldots, X_n) \geq b$
An equal to constraint: $f(X_1, X_2, \ldots, X_n) = b$
(Ragsdale, 1997: 19)

where $f(X_1, X_2, \ldots, X_n)$ is referred to as the left-hand side (LHS) of the constraint, and b is referred to as the right-hand side (RHS) or resource limitation of the constraint (Ragsdale, 1997: 19). The objective, or goal, is represented by an objective function in the general format:

MAX (or MIN): $f(X_1, X_2, \ldots, X_n)$
(Ragsdale, 1997: 19)

The objective function describes some function of the decision variables that the decision-maker wants to minimize or maximize. "The goal in optimization is to find the values of the decision variables that maximize (or minimize) the objective function without violating any of the constraints" (Ragsdale, 1997: 19). The mathematical formulation of an optimization problem in general format is represented as:

MAX (or MIN): $f_0(X_1, X_2, \ldots, X_n)$
Subject to: $f_1(X_1, X_2, \ldots, X_n) \leq b_1$
$f_k(X_1, X_2, \ldots, X_n) \geq b_k$
$f_m(X_1, X_2, \ldots, X_n) = b_m$
(Ragsdale, 1997: 19)

Functions of MP problems can be expressed in linear or nonlinear form, and the optimal values of the decision variables can be expressed in integer or fractional values. Many techniques have been developed to solve various types of MP problems. Linear Programming (LP) is the basis of many of these techniques (Ragsdale, 1997: 20).

2.4.5 Linear Programming and Microsoft Excel SOLVER. Linear Programming (LP) involves MP problems with linear objective functions and linear

constraints (Ragsdale, 1997: 20). LP solvers, such as Microsoft Excel's SOLVER, require the model to be specified by a matrix of coefficients (with rows for constraints and columns for variables) (Compass, 1998). The constraints of an LP model outline the set of feasible solutions, or feasible region, for a problem. The feasible region is "the set of points or values that the decision variables can assume and simultaneously satisfy all the constraints in the problem" (Ragsdale, 1997: 24). The LP model uses the data within the feasible region to determine the optimal solution, or solutions that minimizes or maximizes the value of the objective function. An LP problem is considered infeasible when there is no way to simultaneously satisfy all of the constraints in the problem (Ragsdale, 1997: 33, 37).

An LP problem can occasionally have more than one optimal or alternative solution. This occurs when there is more than one possible outcome or point in the feasible region that maximizes or minimizes the value of the objective function or end goal. Alternate solutions indicate there are two or more ways to meet the same goal (to maximize/minimize the objective). Alternative solutions are anomalies which sometimes occur so they must be considered in the final decision. The Microsoft Excel SOLVER program can provide a sensitivity analysis report for the problem to assist the decision maker identify the existence of alternative solutions so they may be examined for selection preference (Ragsdale 1997).

Many variations of LP problems can be formulated using the SOLVER program through the use of various constraints. An integer linear program restricts the values of the decision variables to assume only integer values. Appendix B contains a sample

integer linear problem for a contract award problem. The objective of the sample problem is to minimize total costs within specific constraints proposed by each offeror. The use of the SOLVER program allows the purchasing agent to determine how much cement to purchase from each offeror and minimize the total costs. The decision variables, or changing cells, in the SOLVER program are stated in integer form due to the integer constraints within the problem. The ability to constrain or limit certain variables to assume only integer form allows the model to express constraints for quantity discounts and minimum purchase order/purchase size more accurately by adding binary and linking variables. Binary variables, Y_i, can assume only two integer values: 0 or 1. Binary variables are useful for depicting and enforcing relationships among decision variables (Ragsdale, 1997).

The sample contracting problem in Appendix B demonstrates how the use of basic LP and integer LP tools provide the means to formulate a generic model for use in determining the optimal solution in sealed bidding acquisitions. The basis for award in sealed bidding is to evaluate the offers and award to the responsible offeror whose bid is the most advantageous to the Government, considering only price and the price-related factors (FAR 14.101(d)(e)). The award goes to the overall, lowest priced offeror whose bid conforms to the requirements of the invitation for bids (IFB). Binary variables permit the addition of constraints for price adjustment clauses. These price adjustment clauses (or price-related factors) add constraints for factors such as discounts, economic price adjustments, transportation costs, life cycle costs, taxes, options, or Buy American Act provisions which must be considered, in conjunction to the total proposed price, to

determine the most advantageous award. Bids can be examined for unbalanced bids or front end loading through the use of Excel's graphics programs. Constraints can also be added to allow award on an "all-or-none" basis or to divide the acquisition into multiple awards. If multiple awards are considered, a constraint to add the $500 administrative fee can be linked to each award using binary variables to determine the individual award or combination of items that result in the lowest aggregate cost to the Government, including the assumed administrative fees. These optimization methods will allow the contracting official to evaluate all proposals to determine the most advantageous award alternative for the Government and to complete the task within the bid evaluation time.

2.4.5.1 Goal Programming and Multiple Objective Optimization.

Additional variations to LP programs include Goal Programming (GP) and Multiple Objective Linear Programming (MOLP) techniques. Goal Programming provides a way of analyzing solutions to decision problems which can be stated as goals with target values. These goals are restated as constraints using deviational variables, which measure the amount of deviation a given solution varies from a particular goal. The objective of a GP problem is to minimize some weighted function of the deviational variable. The weights of the deviational variables can be manipulated to analyze alternate solutions. This feature allows the analysis of trade-offs within problem constraints. A minor alteration which can be implemented for use with GP problems is the MINIMAX objective. This alteration changes the objective function of the problem to allow the program to minimize the maximum deviation of any particular goal (Ragsdale, 1997).

MOLP allows for the inclusion and analysis of secondary objective functions within a single problem. For example, one objective might be to maximize the technical score while the secondary objective might be to minimum costs. Problems with multiple objectives require analyzing trade-offs between the different objectives using the MINIMAX component (Ragsdale, 1997: 276).

GP and MOLP have potential for use in evaluating FAR Part 15 and AFFARS Appendix AA/BB competitive acquisitions. The ability to add weights permits trade-off analysis, the MINIMAX component permits evaluation of multiple objectives, such as minimize costs and maximize technical score, and the ability to select the alternative with the minimize deviation from the target permits a best value decision.

2.4.6 Decision Analysis. Two primary causes that make decision-making a difficult task include uncertainty of the future and conflicting values or objectives (Ragsdale, 1997). The goal of decision analysis is to assist in making good decisions. Using a structured approach to decision-making enhances understanding and perception about the problems faced. Decisions require at least two alternatives to evaluate or solve a problem. An alternative is "a course of action intended to solve a problem" (Ragsdale, 1997: 671). Alternatives are evaluated on the value they attribute to one or more decision criteria. The criteria in a decision problem represent various factors important to the decision maker which are influenced by the alternatives. One problem in comparing alternatives is that not all criteria can expressed in monetary or quantitative values. Also, the values assigned to the various decision criteria under each alternative are dependent upon numerous states of nature which could potentially occur. A state of nature is "a

future event that is not under the control of the decision maker" (Ragsdale, 1997: 670-671). In decision analysis, payoff matrices and decision trees are two tools which allow the decision maker to analyze alternatives given a particular state of nature. A payoff matrix is "a table that summarizes the final outcome (or payoff) for each decision alternative under each state of nature" (Ragsdale, 1997: 672). A decision tree is a graphical form of a payoff matrix. To construct a payoff table or decision tree, each alternative and each possible state of nature must be identified (Ragsdale, 1997). Identification of all possible alternative and state of nature is not always possible in the decision-making process of Government source selections. In addition, the decision makers in a Government source selection often use more than one criterion or objective to evaluate alternatives, and sometimes these criteria conflict with one another. For example, Government SSAs want to reduce performance risk and cost, but simultaneously desire to maximize the technical capability. Trade-offs must be assessed to identify the decision that achieves the most satisfying balance between the opposing criteria. Multi-criteria Decision-making techniques, such as the Multi-criteria Scoring Model and Analytical Hierarchy Process, allow flexibility to assess trade-offs in selection of alternatives (Ragsdale, 1997: 670-715).

2.4.6.1 The Multi-Criteria Scoring Model. The multi-criteria scoring model is "a simple procedure [to] score (or rate) each alternative in a decision problem based on each criterion" (Ragsdale, 1997: 716). The score for alternative j on criterion i is identified by s_{ij} and weights are identified by w_i. In a scoring model, each decision alternative is assigned a value between 0 and 1 to reflect its relative value to the decision

maker. Weights are subjectively assigned to each criterion based upon its relative importance to the decision-maker. A weighted average score is calculated for each alternative as:

Weighted average score for alternative $j = \sum_i w_i s_{ij}$
(Ragsdale, 1997: 716)

The alternative with the highest weighted average score is selected as the best value alternative (Ragsdale, 1997: 716). This technique is similar to some of the scoring methods used in FAR Part 15 competitive acquisitions for calculating a best value award. This method has potential for use in AFFARS Appendix AA and BB source selections, with minor modifications to convert the color coding into a standardized number system.

2.4.6.2 Analytical Hierarchy Process. An enhancement to the multi-criteria scoring model is the analytical hierarchy process (AHP). AHP is used when the decision maker has problems subjectively determining the criterion scores and weights. As stated in paragraph 2.4.2.3, the AHP provides a more structured approach for determining the scores and weights for multi-criteria scoring models (Ragsdale, 1997: 717). The AHP is a decision-making method for prioritizing alternatives when multiple criteria must be considered. It allows the evaluator to structure a problem into a pairwise comparison matrix for each alternative on every criterion. The values assigned in the matrix describe the decision maker's preference between two alternatives on a specific criterion (Ragsdale, 1997). Table 6 provides a preference scale used for pairwise comparison in AHP. This scale is similar to the contracting scale for numerical and adjectival scoring systems shown in Table 2 (paragraph 2.2.2.2.2).

Table 6

Scale for Pairwise Comparison in the Analytical Hierarchy Process (Ragsdale, 1997: 718)

Value	Preference
1	Equally Preferred
2	Equally to Moderately Preferred
3	Moderately Preferred
4	Moderately to Strongly Preferred
5	Strongly Preferred
6	Strongly to Very Strongly Preferred
7	Very Strongly Preferred
8	Very Strongly to Extremely Preferred
9	Extremely Preferred

The AHP process begins by determining the relative importance of the criteria in meeting the goal and their relative weights. P_{ij} identifies the extent alternative *i* is preferred to alternative *j*. Figure 5 provides an example of a pairwise comparison matrix for three alternatives X, Y, and Z in relation to a single criterion, price. The value 1 is placed diagonally along the matrix to indicate that an alternative evaluated against itself is equally preferred because it is the same alternative. Using the scale in Table 6, a decision maker would select his/her preference between X and Y, or P_{xy}; between X and Z, or P_{xz}; and between Y and Z, or P_{yz}. In the scenario in Figure 5, $P_{xy} = 5$ because the decision maker strongly prefers X to Y; $P_{xz} = 7$ because the decision maker very strongly prefers X to Z; and $P_{yz} = 3$ because the decision maker moderately prefers Y to Z. To determine the

values of the decision maker's preferences between Y and X, or P_{yx}; Z and X, or P_{zx}; and Y and Z, or P_{zy}, the reciprocals of P_{xy}, P_{xz}, and P_{yz} are used. The reciprocal formula is $P_{ji} = 1/P_{ij}$ (Ragsdale, 1997).

The next step in AHP is to normalize the pairwise comparison matrix. First, each column in the matrix is summed, then each entry is divided by its column sum and entered in the normalized matrix comparisons table. The average of each row, i.e. for alternative X, (0.745 + 0.789 + 0.636)/3 = 0.724, indicates the relative value of the three alternatives to the decision maker in respect to the price criterion. In Figure 5, X is the most preferred alternative because it has the highest price score (Ragsdale, 1997).

	X	**Y**	**Z**
X	1.000	5.000	7.000
Y	0.200	1.000	3.000
Z	0.143	0.333	1.000
Sum	1.343	6.333	11.00

	Normalized Comparisons			**Price**	**Consistency**
	X	**Y**	**Z**	**Scores**	**Measure**
X	0.745	0.789	0.636	0.724	3.141
Y	0.149	0.158	0.273	0.193	3.043
Z	0.106	0.053	0.091	0.083	3.014
				Consistency Ratio:	0.0567

Figure 5. Price Criterion Pairwise and Normalized Comparison Matrices (Ragsdale, 1997: 721).

A consistency measure (Figure 5) permits the decision maker to verify consistency in preference ratings he/she has assigned in the pairwise comparison matrix. For each alternative, the price scores obtained from the normalized matrix are multiplied by the preferences assigned in the rows of the pairwise comparison matrix. The products are

totaled and then divided by the price score for the particular alternative. For example, alternative X would calculate (0.724 x 1) + (0.193 x 5) + (0.083 x 7)/0.724 = 3.141; alternative Y would calculate (0.724 x .2) + (0.193 x 1) + (0.083 x 3)/0.193 = 3.043; and alternative Z would calculate (0.724 x 0.143) + (0.193 x 0.333) + (0.083 x 1)/0.083 =3.014 (Ragsdale, 1997: 720). If the decision maker is perfectly consistent in assigning his/her preferences, each consistency measure will equal the number of alternatives in the problem. In the problem in Figure 5, n = 3, some inconsistency is demonstrated in the stating of preferences, but some inconsistency is acceptable as it is hard for a decision maker to be perfectly consistent when assigning preferences between a large number of pairwise comparisons. The scores obtained in the normalized matrix are fairly accurate if the inconsistencies are not excessive (Ragsdale, 1997: 719-721). A Consistency Index (CI) and Consistency Ratio (CR) are used to determine whether an inconsistency is excessive. The formulas for CI and CR are:

Consistency Index (CI) = $(\lambda - n)/n - 1$

Consistency Ratio (CR) = CI/RI

where:

λ = the average consistency measure for all alternatives
n = the number of alternatives
RI = the appropriate random index values [from Table 7]
(Ragsdale, 1997: 721)

"If a pairwise comparison matrix is perfectly consistent, $\lambda = n$ and the consistency ratio = 0" (Ragsdale, 1997: 722). The RI values in Table 7 indicate the average value of CI if all the preference ratings entered in the pairwise comparison matrix were chosen randomly, providing that all diagonal entries equal 1 and $P_{ij} = 1/P_{ji}$. If CR $\leq$ 0.10, the

degree of inconsistency is considered satisfactory; if CR > 0.10, excessive inconsistencies might exist and render the AHP results meaningless (Ragsdale, 1997: 722).

Table 7

Values of RI for AHP
(Ragsdale, 1997: 722)

n	RI
2	0.00
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41

The preceding procedures are used repeatedly to obtain the scores for each criterion. Once an individual score is obtained for all criteria, the decision maker determines the weights to indicate the relative importance of each criteria in relation to the other.

The pairwise comparison matrix can also be used to establish and compare the criterion weights. Figure 6 establishes weights to compare three criterion: price, support, and ease of use (Ragsdale, 1997: 724). The last step in analyzing an AHP decision problem is to calculate the weighted average score for each decision alternative. Figure 7 shows a final AHP scoring model solution. Based upon the results of the model, alternative Y has the highest average score (Ragsdale, 1997: 725).

	Price	Support	Ease of Use		
Price	1.000	0.333	0.250		
Support	3.000	1.000	0.500		
Ease of Use	4.000	2.000	1.000		
Sum	8.000	3.333	1.75		
	Normalized Comparisons			**Criterion**	**Consistency**
	Price	**Support**	**Ease of Use**	**Weights**	**Measure**
Price	0.125	0.100	0.143	0.123	3.006
Support	0.375	0.300	0.286	0.320	3.018
Ease of Use	0.500	0.600	0.571	0.557	3.030
				Consistency Ratio:	0.016

Figure 6. Criterion Weights Pairwise and Normalized Comparison Matrices (Ragsdale, 1997: 724).

According to the Vickery (1989) and Noffsinger (1991), AHP was the recommended choice for multi-criteria decision-making in a decision support system. As previously stated, Vickery and Noffsinger advocate AHP as a basis for designing a decision-making model for use in the Government source selection process (Vickery, 1989 and Noffsinger, 1991).

	Alternative			**Criterion**
Criterion	**X**	**Y**	**Z**	**Weights**
Price	0.724	0.193	0.083	0.123
Support	0.230	0.648	0.122	0.320
Ease of Use	0.164	0.297	0.539	0.557
Weighted Avg. Score	0.254	0.397	0.35	1.000

Figure 7. Final AHP Scoring Model (Ragsdale, 1997: 725).

2.4.7 User Interface. A user interface allows the user to control which data and models to use in the analysis. The user interface, the connection between man and computer, should be designed to allow the user to input and extract data as efficiently,

accurately, and quickly as possible. The user interface is the key to obtaining the necessary information from the databases within the system. With proper planning, a user-friendly interface could be designed to interact with the system to allow the user to sort, analyze, and manipulate the data coming into and flowing through the system without requiring the user to know the mechanics of the system (Scott, 1998). The Standard Procurement System (SPS) mandated for use by DoD acquisition offices will become the user interface to electronically access the various information systems required by DoD acquisition personnel. Using the SPS, the user will be able to make inquiries into the DSS and ES and be able to manipulate and analyze data flowing into and out of the model base.

2.5 Conclusion

The SSA has broad discretion in selecting the evaluation factors that apply to a specific acquisition and their relative importance to the total mission requirement, except for price or cost which is always a consideration. The SSA establishes the relative importance of each criterion through the use of decisional rules (weighting the criteria, prioritizing or trade-off statements, or judgmental decisional rules). To evaluate the criteria, various scoring models are used to rate an offeror's proposal including color or adjectival ratings, numerical weights, and ordinal rankings. The AF only restricts AFFARS Appendix AA and BB source selections to the use of adjectival "color code" ratings. For any competitive acquisition below the AFFARS source selection threshold and not using sealed bidding procedures, there is no prescribed methodology for rating as long as it is rational and applied in good faith. The use of a spreadsheet program, such as Microsoft Excel, provides numerous tools to develop a variety of evaluation models

including LP optimization, multi-criteria scoring, and AHP. These models can provide a structured approach to the decision-making process.

In addition, information technology systems, such as DSSs and ESs, are continually improving with advancing technology. Research has demonstrated these systems are being designed using multiple configurations to accommodate various types of business applications. With the right configuration, this advanced technology has the potential to assist the SSA in obtaining and analyzing more complete information through the collection of data into shared data warehouses. The use of DSSs and ESs in the source selection process can permit the SSA to obtain expert advice and decision analysis support on an ad hoc basis. The inclusion of management science tools, such as Microsoft Excel, within the model base of an information system can transform the system from a tactical system into a strategic system.

The following chapter discusses the methodology behind the development of the theoretical schematic model of using information technology to manipulate and analyze information flowing into the source selection process to assist with decision-making. The methodology behind the design and development of the Microsoft Excel baseline models is also discussed in Chapter 3. The LP optimization, multi-criteria scoring, and AHP tools are the focus of the design and development of the baseline models.

3. Methodology

3.1 Introduction

This chapter outlines the data collection and analysis method used to answer the investigative questions previously posed. Answering these questions allows assessment of the strategic role of information technology to assist the SSA evaluate and analyze multiple alternatives during the decision-making process of a competitive source selection.

3.1.1 Investigative Questions. The investigative questions are:

1) Can a schematic model be designed to identify areas where information technology can improve the flow of information into the source selection evaluation process and expand the present tactical approach to evaluation of alternatives into a more strategic approach?

2) Can a baseline model be designed, based upon Microsoft Excel SOLVER, to assist the SSA in choosing the best alternative source in a competitive source selection?

3.1.2 General Approach. The primary methods of solving the research problem include a combination of case study and grounded theory approaches. The case study approach was used in three ways. It was used in collecting, organizing, and reporting the information on the boundaries set by contracting source selection policies and regulations. It was used to examine the types of information technology available to automate the flow of information into the source selection process while remaining within contracting boundaries. Finally, case studies were used to analyze literature relating to the various modeling techniques contained in Microsoft Excel to identify which techniques are best for

use in the source selection process. Additionally, the case study approach was used as the basis for the development of the schematic information model.

A grounded theory approach was used as the basis for development of the Microsoft Excel SOLVER models. Data from historical contract files was systematically gathered and analyzed as the models were being developed. As the continuous inflow of data affected each model's development, its design was re-analyzed and modified accordingly.

3.2 Schematic Model Development

The schematic information flow model was developed after an extensive literature review of primary and secondary data sources on the topics of the acquisition process, information technology systems, and management science techniques. Commercial information systems used in decision-making and in evaluating and analyzing multiple criteria decisions were reviewed to determine the most feasible information technology solutions to automate the flow of information required by the SSA to make a sound decision. Information flowing into the source selection process was analyzed for its applicability to assist the SSA in making an optimal decision, and its potential for automation. A theoretical model based upon system application, benefits, features, and capabilities was designed to flow information into the Microsoft Excel SOLVER model base for analysis.

3.3 Microsoft Excel SOLVER Decision Model

Design and development of a baseline SOLVER spreadsheet, was addressed by focusing on the general evaluation criteria, decisional rules, and scoring models used as

the basis for awards in sealed bidding, competitive proposals, and AFFARS Appendix AA/BB source selections. Current contract policy and regulations on the evaluation and award process (paragraphs 2.1 - 2.2) defined the boundaries of the basic models developed. At the Aeronautical Systems Center, Wright-Patterson AFB OH, permission was granted by the SSA for DAC Programs and Other Contracting acquisitions to search archived contract files for data pertinent to the development of a baseline model. Authority was not granted to access contract files using AFFARS Appendix AA formal source selection procedures so no Appendix AA contract data was used to develop the baseline models. Contract files were identified and located using the current contracting Automated Management Information System (AMIS). Contracts were "tagged" for use by special identifiers within the AMIS system. These identifiers indicated whether the contract was awarded as a competitive or sole source acquisition; and whether the use of sealed bid, competitive proposal, or formal source selection procedures were used. Contract files using AFFARS Appendix BB procedures were reviewed at ASC/SY, the Source Selection facility. At ASC/PKW, the managers of the construction and specialized services branches manually identified and provided appropriate contract files for review. These two branches were selected due to the nature of the acquisitions. Construction acquisitions normally used sealed bidding procedures, and specialized services normally use FAR Part 15 procedures implementing the lowest priced technically acceptable basis of award. At ASC/PKW, contract files using sealed bidding, FAR Part 15 competitive procedures, and some AFFARS Appendix BB source selections were reviewed.

Data collected from the contract files answered the following questions:

1. What type of acquisition procedures were used? Sealed Bid, Competitive Procurement, AFFARS Appendix BB.

2. What was the basis for award? Lowest priced bid, Lowest priced, technically acceptable, Best value.

3. What was the structure and number of Contract Line Items (CLIN) in the solicitation? And what was the type of contract, i.e. basic IFB, RFP, or requirements/indefinite delivery, indefinite quantity contract?

4. What were the evaluation criteria in the solicitation?

5. What type of constraints were mandated by the solicitation, i.e. single aggregate or multiple awards, small business set-aside, responsive or responsible contractor, FOB destination/origin?

6. How many contractors submitted an offeror?

7. What did each contractor propose?

8. What were the results of the evaluations, i.e., color codes, risk ratings?

9. What was the SSA decision?

General trends were identified for each type of acquisition procedure, and this type of data was incorporated into the baseline models during spreadsheet design to add realism to the models. Common constraints were identified for each type of product acquisition to assist in determining ease of modifiability between the models. Once the baseline models were complete, usability and accuracy of each spreadsheet model was verified and validated by incorporating actual data collected from competitive bids and proposals. The verification/validation phase also helped identify benefits/advantages and potential problems/disadvantages of these models.

*3.3.1 **Baseline Models.*** The baseline models were designed using mathematical programming techniques and the Microsoft Excel SOLVER software program. Integer Linear Programming (ILP), and Multi-criteria Scoring/AHP methods were identified as the most promising methods for model development. Four steps were used to develop the ILP optimization models:

1. Organize the data for the model on the spreadsheet.
2. Reserve separate cells in the spreadsheet to represent each decision variable in the model.
3. Create a formula in a cell in the spreadsheet that corresponds to the objective function in the model.
4. For each constraint, create a formula in a separate cell in the spreadsheet that corresponds to the left-hand side (LHS) [and right-hand side (RHS)] of the constraint. (Ragsdale, 1997: 45).

A single baseline using ILP was developed for sealed bidding acquisitions since the technical nature of sealed bid evaluations was less complex. A separate spreadsheet using AHP was used to design the baseline for formal source selections. Due to the variety of evaluation criteria options available for use in FAR Part 15 competitive acquisitions, the two baselines (ILP and AHP) were then modified into a single model to determine if they could meet the requirements for competitive acquisitions procedures.

*3.3.2 **Baseline for Sealed Bidding.*** An understanding of the "lowest bid" basis for award in sealed bidding acquisitions (FAR Part 14) was required for development of this baseline. The evaluation criteria and data on sealed bidding described in paragraph 2.2.1 was used, in conjunction with actual data from contract data files, to determine the best approach for model design. ILP was used to develop the sealed biding model.

*3.3.3 **Baseline for AFFARS Appendix AA/BB Source Selections.*** An understanding of best value awards was required for the design and development of the

baseline for AFFARS Appendix AA/BB formal source selections. Both AFFARS Appendix AA and BB source selections use the evaluation procedures identified in paragraph 2.2.2.3 so a single model was developed for use by both types of source selections. Using the Microsoft Excel software, model data was examined and input using the multi-scoring and analytical hierarchy approaches for multi-criteria decision-making. The AF requires technical data to be evaluated using color ratings (blue, green, yellow, and red). Quantitative measures were assigned to colors to measure the differences in the descriptive data. Since past performance data is also evaluated using color ratings, the same measurement scheme was used. Pairwise preference matrices were developed at the lowest possible level to permit consolidation of input from multiple technical evaluators. The model was designed to permit the flow of information to higher levels of evaluation (factor, subfactor). Once the technical data and past performance data were incorporated into the decision model using the color coded rating scale, the cost data was incorporated using a preference scale similar to Table 6. A pairwise matrix for the criterion weights was developed, in to incorporate the technical, past performance, and cost data, into a final AHP pairwise matrix for determination of the best value alternative. The evaluation criteria and data on AFFARS Appendix AA/BB described in paragraph 2.2.1 were used, in conjunction with actual data from contract data files, to determine the best approach for model design. Due to a wide variation among contracts on the basis of award and/or selected evaluation criteria, the model was designed generically for flexibility and easy adjustments.

*3.3.4 **Baseline for Competitive Proposals.*** The baseline for the Competitive Proposals (FAR Part 15), was developed last as the evaluation procedures could be similar to either those used to develop the AFFARS Appendix AA/BB formal source selection baseline or the sealed bidding baseline. The main differences to consider were basis of award, and the rating methods applied to evaluation of the technical criteria. The color rating system was not mandatory for competitive proposal acquisitions which did not meet the thresholds of AFFARS Appendix AA/BB source selections so the other rating methods described in paragraph 2.2 were optional for use by the SSA. A small number of contract files were reviewed to determine which rating methods were commonly used to evaluate the technical and past performance data, and how to incorporate this information into the model. The lowest priced technically acceptable basis of award appeared to be most frequently used in FAR Part 15 acquisitions. A common rating method for these acquisitions was to rate the technical proposals on the basis of Acceptable, Marginal, or Unacceptable. Due to this, the ILP optimization model was selected for review. The technical data were incorporated using binary and linking constraints into the decision model, and then merged with the cost data to determine the optimal award based upon the award lowest priced technically acceptable criteria

*3.3.5 **Model Verification***. To achieve a logical spreadsheet design, the following goals were considered during the creation of each baseline model, and were used as the basis to evaluate the final models developed:

1. *Communication* - The primary design objective of a model is to communicate relevant aspects of the problem in a clear and intuitively appealing manner.
2. *Reliability* - The output of the spreadsheet should be correct and consistent.

3. *Auditability* - The model should be setup in an intuitively appealing, logical layout to allow readers to retrace the steps followed to generate different output. This will assist with ease of understanding and verification.

4. *Modifiability* - The data and assumptions in which the spreadsheets are built will change frequently. To accommodate for changing user requirements, the spreadsheet should be designed for easy modifications or enhancements. (Ragsdale, 1997: 59)

Communication was examine regarding three points: how effective the model's design was for presenting final results to the SSA, how effective was the spreadsheet's formatting to communicate the mechanics of the model to users using colors and other techniques. Reliability was examined for accuracy, consistency, and effectiveness of spreadsheet design, AHP and ILP techniques, and the Microsoft Excel SOLVER program. Auditability was examined for ability to retrace data output to its source of input between worksheets, ability to track and update formulas, and formatting techniques used to identify common features among input. Modifiability was examined for ability to generate new models using copy/paste/edit techniques, ability to modify the spreadsheet to accommodate new or changed acquisition data, such as increases or decreases in the number of offerors, CLINs, or evaluation criteria; changes resulting from clarifications and discussions with offerors, and changes in the number of limitations or constraints.

3.4 Conclusion

The techniques identified in this chapter were used to collect, organize, and analyze the data used to develop the schematic and baseline models constructed in this study. The

following chapter describes the design and development of the models and the resulting analysis.

4. Model Development and Analysis

This Chapter presents the findings and analysis of the models developed during this research. The schematic model is a theoretical model of how the source selection process could be automated to collect, manipulate, and analyze information to assist the source selection decision-making process. The models developed were designed within the constraints placed upon the current source selection process by contracting regulations, laws, and policies. A more effective and efficient model may be feasible if waivers were granted to deviate from current regulations regarding adjectival color coding, or the allowability to compare an offeror's proposal against its competitors.

4.1 Investigative Questions

1) Can a schematic model be designed to identify areas where information technology can improve the flow of information into the source selection evaluation process and expand the present tactical approach to evaluation of alternatives into a more strategic approach?

2) Can a baseline model be designed, based upon Microsoft Excel SOLVER, to assist the SSA in choosing the optimal or best alternative source in a competitive source selection?

4.2 Investigative Question Number One: Development and Analysis of a Schematic Model

At the conclusion of the literary research on information technology and the flow of information into the source selection process, a theoretical model (Figure 8) of a

Decision Support System, using an "intranet" philosophy, was designed to assist the SSA choose the best alternative for contract award. An intranet is a computerized network connecting people, data, processes, and other workings of a particular business entity—DoD procurement offices—into a business-wide web (Lewis, 1998: 1). The complexity of the Government source selection process requires SSAs to be able to analyze and manipulate data in an ambiguous and complex environment. This theoretical model could be used to evaluate sealed bids, competitive proposals, or AFFARS Appendix AA/BB source selections, however the following discussion in reference to Figure 8 is limited in use to AFFARS Appendix AA/BB source selections.

By the year 2000, offeror cost and technical proposals will be delivered to the source selection team through the use of an EC/EDI or internet system (SAF/AQXA, 1997). The DoD SPS acts as the user interface, or link, between the SSAs and the information stored within the various shared data warehouses. Its use of relational databases links the data within the system and should allow the source selection team to conduct ad hoc queries during the decision-making process. The source selection team, through operation of the user interface, can access the inference engine to obtain advice, regulation, and historical information. The inference engine can be used to solve problems before and during a source selection by accessing and analyzing information from the DSS knowledge base. The knowledge base in the theoretical model consists of two expert systems and an additional DSS within the knowledge base to form an "expert shell." The additional DSS contains historical records of source selections, lessons learned information obtained during previous source selections, historical data on contract awards,

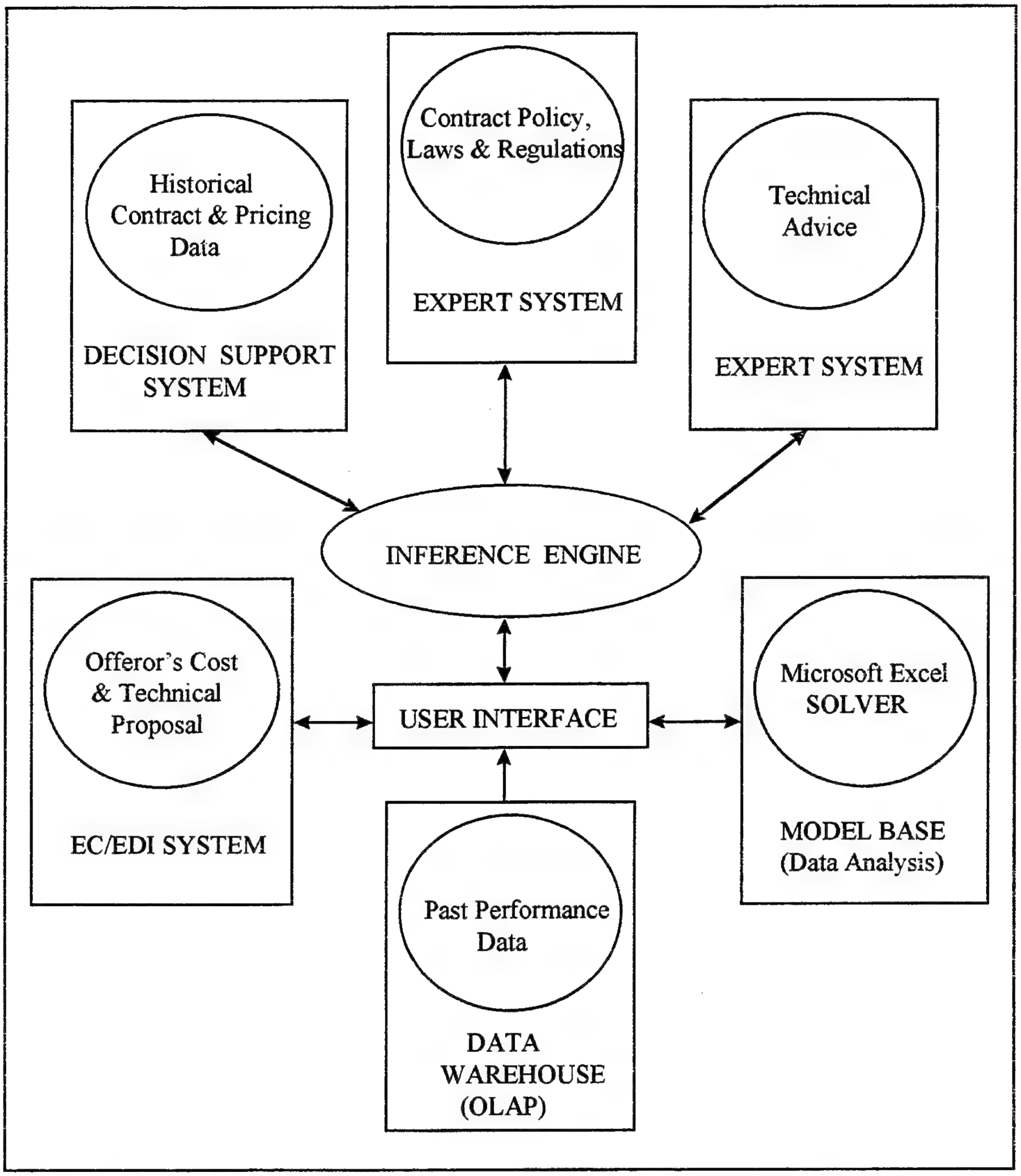

Figure 8. Schematic Model of Information Technology, Decision Support System, in the Source Selection Process.

cost and pricing evaluation data on past awards, Government cost estimates for current source selections, funding data for the acquisition, and the source selection evaluation criteria and standards for the current acquisition. The DSS would be able to use case-

based reasoning, together with "what if" capabilities, to allow the source selection team to ask ad hoc questions which are unique to each individual acquisition. In conjunction, an expert system with AI capabilities is linked to the additional DSS to act as a consultant by providing expert contracting, source selection, and legal advice. In addition to the rules and opinions from experts in the contracting and legal field, this expert system contains all of the contracting rules, regulations, and policies; source selection regulations; and acquisition legal cases, such as General Accounting Office (GAO) case reports and protest court cases. A second ES with AI capabilities, is used to provide technical advice for program personnel and engineers during technical evaluations. Rules and expert opinion on factors such as engineering design and development techniques, production and process control, reliability and maintainability measures, technical data and drawings of existing systems, logistics and transportation data, and standards for the number of hours to perform a task are contained in the database of this expert system.

The AI expert systems within the knowledge base would allow the inference engine to deduce information and also ask questions regarding information that it couldn't analyze. The source selection team could use the DSS at this point to ensure each proposal has complied with contracting and legal policies. The knowledge base can be used by the inference engine to assist the evaluation team compare each offerors proposal against the minimum mandatory requirements (paragraph 2.2.2.3.1) to determine minimum compliance with requirements. If minimum mandatory requirements are used to determine the competitive range, the DSS could provide an initial evaluation of proposals and rate them on a pass/fail or green/red basis by determining which offerors met the mandatory

requirements. The source selection team could then use the data provided by the DSS to determine which proposals continue into detailed evaluations. Proper planning during the pre-solicitation phase of the acquisition would be required to solidify the minimum standards required to meet the evaluation requirements established to allow the computer to scan each proposal to determine compliance. Once the SSA agrees with the analysis of the competitive range determination, the system could generate notices to the unsuccessful offerors (proposals rated "red") and notify them electronically via EC/EDI or internet.

If minimum mandatory requirements were not pre-established, the source selection team could begin by evaluating the Essential Characteristics (paragraph 2.2.2.3.1) of the proposals using the Microsoft Excel Model Base. When evaluating the Essential Characteristics, the AF requires the use of the adjectival color coding scheme (blue, green, yellow, red) to determine how well each offeror rates in comparison to the pre-established evaluation criteria. The team assesses criteria at the element level using symbols (+,√, -), and proposal and performance risk using descriptive adjectives (high, moderate, low). The DSS could be used for advisory assistance during this portion of the technical evaluation.

Proposal cost and pricing data could be analyzed for realism and reasonableness using the historical data and the Government estimate in the DSS. The technical team could use the technical expert system to obtain information on labor standards to calculate the number of hours and the skill mix required to successfully complete a task. This would provide a more objective basis for the evaluations, and also assist the technical team assess the soundness and realism of the offerors technical approach. The historical files

could be searched for labor rates, material costs, and other relevant costs to assist in determining the reasonableness of the offer. A link to the internet could also be incorporated to obtain current pricing on materials, as many companies are now advertising numerous products and services on General Service Agency (GSA) government pricing schedules on the World Wide Web. Expert audit advice, along with DCAA audit reports, could be included in the DSS database to permit queries regarding overhead, general and administration, profit, effects of proposed changes in contract type on costs, and risk analysis. Statistical graphics could assist examination of front-end loaded or unbalanced bids by showing each offeror's costs in relation to the Government estimate and its competitors.

Past performance data, analyzed and obtained from the shared data warehouse, could be used in conjunction with sources of past performance information provided by the offeror, to determine risk associated with offeror performance based upon an integrated assessment of the offeror's past history. Until recently, past performance was normally considered a general consideration during the evaluation process, but has now increased in importance. It is now usually considered a specific evaluation criteria.

To conduct statistical analysis on the data within the past performance data warehouse, an on-line analytical processing component would be required. Input of CPARs data in the correct format could allow the system to analyze the data to show past trends in contract cost over-runs or completion under cost, on-time or late deliveries and schedule compliance, and to rate the quality of products or services delivered, i.e., compliance with specifications, deviations due to contractor fault, and superior or above

minimum quality. Statistical analysis could be used to analyze past trends and to predict and assign a probability rating factor on future performance. The data warehouse could provide both a detailed and summary report on the analysis, along with the probability factor, to allow the source selection team to incorporate additional external past performance information provided by the contractor or other sources not contained within the CPARS system.

Once the technical and past performance data are evaluated, the source selection team would then direct this information into the model base, along with the cost/price evaluation information, for analysis of the optimal solution to determine which alternative offeror is best. The model base includes various scoring models, statistical software, optimization models, and software necessary for the analysis of the proposed alternatives. The SPS interface would need to permit the source selection team to input and analyze the data using the model base without having specific computer or mathematical expertise. The model base could construct the specific evaluation model in response to data input by the source selection team, i.e., computer asks number of offerors to be evaluated, and the number of evaluation criteria and preferences (color codes), and the computer builds an evaluation matrix based upon user response. The model base incorporated in this DSS model contains the Microsoft Excel SOLVER program. Other analytical software programs can be included within the model base as necessary. Once the model base has evaluated and determined the optimal solution, the information is sent back to the user for source selection consideration. Once the SSA agrees with the decision provided by the team, award can be made through the EC/EDI or internet.

A simple theoretical model for less complex acquisitions, such as sealed bidding, might consist of an EC/EDI or internet system to input the proposal data into a Government database, which in turn could flow the relevant information into the model base, or optimization program. Since the SPS system uses standardized ANSI X12 documents, the relational database could sort data from specific fields in the proposal document and redistribute it into the model base using Microsoft's Access database features. The system could then analyze the data for inconsistencies (i.e., error in the addition of proposed unit prices and quantities to the extended price) and notify the contracting official for potential errors or abnormalities in the proposal data. The contracting official could visually analyze the data to determine if the offeror would be considered responsive or eliminated from further competition. Once the contracting official has determined the data is correct, the proposal information could be electronically re-submitted to the SOLVER program for determination of the optimal solution.

As stated earlier, these are theoretical models developed from literary research. Prior to development and implementation of a model for contracting, a field study should examine the mechanics of actual DSS and expert systems to ensure benefits and features cited in the literature provide the necessary level of technical operability required to support a source selection. This field research is important as a system designed to meet the constraints of Government contracting regulations and laws would differ from the multi-criteria evaluation systems designed for commercial business applications, such as selecting which product to take into full-scale production. The technology exists to meet

the requirements but modifications may be required to fully implement the applications within the Government contracting field.

4.3 Investigative Question Number Two: Development and Analysis of the Microsoft Excel SOLVER Baseline Models

The Microsoft Excel Spreadsheet Models designed and developed in this section represent part of the model base as described in the previous section. The models are developed for manual input by a contracting official as no interface device currently exists to provide connectivity with receipt of electronic data. These models are designed to assist the decision-maker evaluate source selection information, not to replace the decision-maker.

4.3.1 FAR Part 14, Sealed Bidding Procedures. The Microsoft Excel SOLVER program using ILP was used to design the model for the Sealed Bidding Procedures, FAR Part 14. Windows 97 was used in the development of this model. Appendix C, Figures 20 - 24 provide visual data of charts from actual models developed. Appendix C, Table 8 provides the SOLVER parameters and options necessary to solve the ILP problem. The sealed bid model was designed based upon the lowest priced responsive bid concept. The model was arranged to permit the contracting official to input specific background data, and to receive some direction from the initial "Acquisition Background" worksheet. Two SOLVER models were designed to permit award of either a single, or "aggregate" contract; or to permit split, or "multiple" awards. If the solicitation permitted multiple awards, the contracting official must use both of the models in the "Sealed Bids – Aggregate" and "Sealed Bids – Multiple" worksheets to allow comparison of the best

alternative to the Government. The models were designed to reduce the amount of data entered into the spreadsheet by the contracting official by using "=CELL ADDRESS" formulas in the price and quantity cells (Figure 20) for the "multiple" award model. This permitted the automatic transfer of data from the "Sealed Bids – Aggregate" worksheet into the "Sealed Bids – Multiple" worksheet. A third worksheet "Unbalanced Bids" using graphics was provided to permit analysis of offeror's proposals for indications of unbalanced bidding or front-end loaded bidding. Fill-in data from the "Unbalanced Bids" worksheet would be transferred to both the "Sealed Bids – Aggregate" and "Sealed Bids – Multiple" worksheets.

In the "Sealed Bids – Aggregate" worksheet, the contracting official must input the offerors proposed price and quantity required by the government. After review of ASC/PKWO's construction contracts using sealed bidding procedures, it was determined that a model incorporating six offerors and four CLIN would be adequate for development. Theoretical prices and quantities were incorporated into the model, using numbers easy to calculate without the use of the SOLVER, to permit evaluation of the model's ability to provide a solution. Formulas, using "=SUMPRODUCT" or "=SUM" were entered into the model to calculate the totals of the columns and rows, respectively, for the price and quantity data. The target cell, or the cell the SOLVER program was to minimize, was the "Total Price" cell (Figure 22). An "=SUM" formula was entered into the target cell. Binary constraints, or changing cells, and Linking constraints (Figure 21) were added to the aggregate award model to restrict the SOLVER from selecting more than one offeror for award. This restriction, nor the corresponding section in Figure 21,

was not required for the SOLVER to determine the lowest price in the multiple awards model, as it searches for the lowest priced CLIN among all offerors and awards multiple contracts based upon lowest overall price. Binary constraints were used to incorporate information regarding solicitation constraints and to determine whether or not the offerors complied with these constraints (Figure 23). These constraints included data on small business restrictions, unbalanced bidding, front-end loaded bidding, and offeror responsiveness; however the method devised to incorporate these constraints could be used to incorporate numerous other constraints mandated within the acquisition field. Each qualitative constraint was established to answer a specific "yes" or "no" question. A "yes" answer was then converted to a "1" and a "no" answer was converted to a "0." A binary summary answering the question "Was the requirement met?" was created and were linked to the SOLVER program using the formula "=IF(AND(BS_1, BS_2, BS_3, BS_4,BS_5),1,0), where BS = binary summary." This formula translated means "if all of the five constraints are true (reflected by a "1" in the model), then input "1," otherwise "0." Using the constraint D33:I33 $\leq$ D109:I109, or the "Binary: Contractor Used" cells (Figure 21) must be less than or equal to the "If all constraints are met, then = 1, if not met then 0" (Figure 25). This constraint prevented an offeror who did not comply with the requirements of the solicitation from receiving award even if he was the offeror with the lowest price.

The "Sealed Bids – Multiple" model was designed through modification of the "Sealed Bid - Aggregate" model. The model initially resembles Figure 20 of the aggregate model for price and quantity, except the formulas "=CELL ADDRESS" were

inserted into the fill-in sections to prevent the contracting official from re-entering the offeror price and quantity required a second time. Figure 24 demonstrates the differences between the aggregate and multiple awards models. The multiple award model had a requirement to add $500 per contract awarded to evaluate if the additional administrative costs of awarding multiple contracts was more beneficial to the Government. Since the $500 administrative fee was only for evaluation, it was not added as a constraint within the SOLVER model. This separation permitted the evaluator to compare the total price including the administration fee with the total price calculated in the aggregate model to determine which method of award provided the lowest overall cost to the Government. If the determination was that multiple awards were the most beneficial, then the contracting official could use the answers provided from the SOLVER program to differentiate which offerors would receive award, which CLINs would be awarded to each offeror, and the amount of each offeror's total award.

4.3.1.1 Communication. The magnitude of the spreadsheet required to incorporate all of the data necessary to solve the problem, made communication of the data difficult. Reducing the size of the spreadsheet to 40-50%, permitted the evaluator to review a significant portion of the data, however the text became quite small. Color codes were used to assist with easier communication of data. Cells were highlighted in red wherever the contracting official was required to insert data about the acquisition or the offeror. The changing cells, the quantities and the binary constraint cells, were a dark grey; and the target cell, or total price, where SOLVER provides the final solution was dark blue. The total price in the "Quantity Offered Per CLIN" matrix was also highlighted

light blue to indicate which offeror would receive award and the amount of the award. Yellow "reminder" cells were added beside cells requiring constraints to be input into the SOLVER program (Figure 22). Light green cells were incorporated to provide information on specific formulas used within a group of cells (Figure 22). These are just some of the ways colors were used to communicate information to the contracting official.

The layout of the spreadsheet facilitated communication regarding the solution through placement of information cells at the beginning of the spreadsheet (Figure 20 and Figure 22). The total price cell (Figure 22, dark blue) provided the solution generated by the SOLVER program and reflected the minimum aggregate price to the Government. The total price cells (Figure 20, light blue) provided the amount each offeror would receive for their individual award or a zero indicating no award. The SOLVER computed the quantities each offeror was to be awarded and included the amount in the changing cells. In the aggregate model, only one offeror could be selected so all of the quantities for each CLIN were constrained to a single column. The "Total QTY" column (Figure 22) indicated whether or not the SOLVER solution met the Government's required quantity levels input by the contracting official. The SOLVER replaced the changing cells in the binary matrix to either "1" or "0," dependent upon whether the offeror had received an award or not (Figure 21). The "Binary: Contractor Used" row showed which offeror had met all of the constraints and should receive award. The SOLVER program inserted a "1" in the cell for the offeror who had the lowest price and met all of the constraints. All of the data necessary to determine which offeror should receive award in at the beginning of the spreadsheet, except for verification of the binary variable summary for the

constraint cells. (Figure 25, constraint summary is the same for both models). Since this binary summary was used only for verification, placement after all constraints seemed plausible.

4.3.1.2 ***Reliability.*** The reliability of the SOLVER program to consistently and accurately provide the correct solution was in question. Manipulation of the price and constraint data input into the spreadsheet revealed some problems with the SOLVER programs ability to perform accurately using modified data once the SOLVER program has been run. At one point during analysis, the SOLVER program had provided a correct solution (based upon manual calculations for verification); but continued to provide the same solution when the pricing data for another offeror, who met all of the constraint requirements, was manipulated to a very obvious lower price solution when calculated manually. Regardless of how the data was manipulated, the SOLVER program continued to generate the solution it had originally obtained. Later examination revealed the SOLVER was operating correctly. No determination could be made as to the cause of this problem, whether it was a gliché in the Windows 97 program or some other cause. It could have resulted from SOLVER's ability to manipulate the data as it was formulated in the spreadsheet models, but this seems an unlikely cause. One method to counteract this problem would seem to be reconstruction of a new model for each new acquisition; rather than modifying the model, however this is very time-consuming and inefficient. For the benefit received from the development of this model, a new reconstruction does not seem feasible for each new sealed bidding acquisition determined to be an aggregate award. If a computer could be developed to design the models for the contracting official, with more

accuracy in the solution, it might become feasible. If multiple awards were authorized, the ability to compare the results of the two models might make the reconstruction feasible. Further research is required to determine the cause of the model's gliche before the model can be considered reliable.

Another reliability consideration resulted from modification of the model. Errors were easily made when using the copy/paste/edit method of recreating a second model. The second model had to be pasted into the same rows and columns as the first model (different worksheet) to permit stringed cell addresses to locate the correct answer. If the second model was copied into a new spreadsheet document, it became almost mandatory to verify the accuracy of the formulas in every cell.

4.3.1.3 Auditability. The ability to track information throughout the document is difficult due to its enormous size. Copying and pasting formulas from one cell to another, placement of reminder cells within the spreadsheet to add constraints in the SOLVER program, and color coding cells were some of the methods employed to assist with the tracking of information throughout the spreadsheet.

The use of stringed address cells (i.e. $L$4) during the development of the model prevented data from being changed as it was copied from one cell to another. This permitted easy verification the data in the cells were accurate. However, the use of stringed address cells caused minor problems for the creation of new models to be developed based upon the copy/paste/edit method.

4.3.1.4 Modifiability. The sealed bid-aggregate model was designed and created initially and used as the basis to develop the sealed bid-multiple and the

competitive proposal-FAR Part 15 models. As previously stated, the use of stringed address cells caused minor problems and it became mandatory to verify the formulas copied in every cell to ensure the formulas were correct. Knowing the exact solution to the problem made it easy to know when the model was accurately solving the problem; however, modification was time-consuming as several iterations of the SOLVER program had to be run, and minor errors corrected, before the correct answer could be obtained.

4.3.1.5 Model Limitations. The generation of an evaluation model for the assessment of offerors proposal information was successful; however, the reliability of the Microsoft Excel SOLVER Program to consistently generate accurate solutions in these models was questioned. This inconsistency could be the result of the Windows 97 SOLVER software or due to other causes, such as SOLVER's ability to manipulate the data in this particular model. This accuracy factor was seen as a major limitation in the use of the Microsoft Excel SOLVER program for decision-making in source selection. SSAs require accurate information 100% of the time and it has not been determined how reliable the SOLVER model is at total accuracy. Further investigation is required to make that determination.

4.3.2 AFFARS Appendix AA/BB Procedures. The AHP process was used to design the model for the AFFARS Appendix AA/BB source selection process. One problem encountered during development was devising a method to assign preferences within the pairwise matrix without comparing an offeror's proposal against its competitors. To alleviate this problem, the mandatory AF color coding rating system was used to evaluate each offeror against the standard for each criteria. Once a color code

was assigned to the criteria at the element level, the data was input into the model for each offeror. A standard numerical rating system was then symbolically applied to the color codes to convert the qualitative data into a quantitative means of evaluation.

Windows 95 was used for model design and evaluation of the AHP model. Design of the model began after a thorough literature review of the acquisition regulations and examining several contract files to observe the level of information required by the SSA to make an effective decision. Based upon the results of this research, the model was constructed to begin input of information at the element level of evaluation. A hypothetical acquisition was devised in which the source selection participants included three offerors (1, 2, and 3), four technical evaluators at the element level for each subfactor, a factor/subfactor team chief for each factor (4), a cost/price evaluator, a past performance evaluator, and the SSA. Multiple worksheets were developed to segregate various types of data at the different evaluation levels (factor, subfactor, element). The worksheets in the model start at the highest level of information, and subsequently furnish detailed data at the lower levels in each worksheet beneath. The "Final AHP Evaluation" worksheet demonstrates the optimal solution to the problem by indicating the highest rated offeror as the best alternative choice. The "Criteria Weights" worksheet compares the preferences or ranking of the factor criterion "Technical, Cost/Price, and Past Performance" in relation to each other and calculates a weighted score for each factor using the pairwise matrix. The "Technical Factors" worksheet takes the data from the "Technical Factor Ratings" worksheet to calculate AHP scores for each factor using the pairwise matrix. The "Evaluator Elements Ratings" worksheet provides the input into the

model from the individual technical evaluators at the element level to permit the team chief to subjectively convert the data into a subfactor rating. The "Cost/Price" and "Past Performance" worksheets use color coded input from the source selection team to determine AHP scores using the pairwise matrix. Three additional worksheets were provided to furnish summary data at the element and subfactor level. These worksheets, "Subfactor Averages," "Technical Element Summary," and "Technical Elements" were provided for informational purposes to consolidate and communicate the detailed information from the "Evaluator Element Ratings" worksheet should the SSA require additional information.

Numerous levels of subfactors (4) and elements (2-4) were generated to determine the flexibility and difficulty of modifying the model based upon minor changes which could occur in different acquisitions. Initially a worksheet "Evaluator Element Ratings" was devised to input the color codes from each technical evaluator at the element level of criteria evaluation. Figure 9 demonstrates the level of input provided by the technical evaluator at the element level. At the element level of evaluation, acquisition regulations permit the use of either color coding (red, yellow, green, blue) or symbols (plus (+), a check (√), and minus (-)). It should be noted that a limitation observed within the Microsoft Excel spreadsheet program was the inability to easily place a check (√) symbol into the program. Due to this limitation, color coding was used as the scoring system to input evaluation data obtained from individual technical evaluators. Once the data was input into the model, the factor/subfactor team chief must consolidate the information at the subfactor level and provide a subfactor rating. A second limitation which was noted

Evaluator 4

Offeror	1	2	3
Factor 1 -			
Subfactor 1			
Element 1	B	G	R
	1	10	1000
Element 2	G	G	Y
	10	10	100

Overall Rating

Offeror	1	2	3
Factor 1 -			
Subfactor 1			
Element 1	B	G	R
RYGB	0013	0130	4000
Element 2	G	Y	Y
RYGB	0031	0310	0310

Figure 9. Technical Rating Chart of a Single Evaluator, and Overall Summary of Subfactor Ratings Chart Resulting from Consolidation of Technical Rating Charts.

with the AHP model was its inability to flow model scores obtained from AHP pairwise matrix at the element level into higher levels of the model due to the preference criteria. At each new level, the AHP model required data entry of the "preferences" based upon a rating scale required at that level. To eliminate this problem and to permit the team chief to observe the ratings of the individual evaluators within a single screen setting, a frequency count scoring mechanism was derived to count the number of colors per offeror for all evaluators and provide a summary total to the team chief in the Overall Rating table. In Figure 9, the color codes red "R," yellow "Y," green "G," and blue "B," equate to R = 1000, Y = 100, G = 10, and B = 1. So offeror 1 was evaluated for Factor 1, subfactor 1, element 1 as having zero red, zero yellow, one green, and three blue (0013). The team chief could now "roll-up" the subfactor color code scores into the next level of evaluation. The methodology used in Figure 9 was accomplished for each subfactor under all factors.

In Figure 10(b), the formula "=CELL ADDRESS" (i.e. "='Evaluator Element Ratings'!Z14") was entered into an Element cell of the Overall Subfactor Rating chart, and

copied, and edited accordingly so each element cell would automatically be updated should the evaluator information in the "Evaluator Element Ratings" worksheet be modified. An overall subfactor rating chart was developed for each subfactor. Subfactor color code scores were assigned a numeric symbol (Figure 10(a)) to standardize the differences in the scores based upon preference. Since the color code red "R" was the least desired outcome, indicating an unacceptable rating, it was assigned a symbol of "1;" yellow "Y" indicates a marginal rating so it was assigned a symbol of "5;" green "G" indicates an acceptable rating so it was assigned a symbol of "8;" and blue "B" indicates an exceptional rating so it was assigned a symbol of "10." The logic for these rating symbols was to permit subtraction of the numbers so the difference between color code ratings for each offeror could be equitably compared. The formula:

=IF(E10="R",$L$2,IF(E10="Y",$L$3,IF(E10="G",$L$4,IF(E10="B",$L$5)))

was entered into the spreadsheet cell below each element rating color code so the computer would automatically translate the color code into a numeric symbol. Translation of the formula means, "If the color code in cell E10 is R, then input a 1; if the color code in cell E10 is Y, then input a 5; if the color code in cell E10 is G, then input an 8; and if the color code in cell E10 is B, then input a 10." Stringed cell addresses (i.e. $L$2) were used in the formula rather than actual numeric symbols (1, 5, 8, 10) to permit flexibility in the model should it become necessary to modify the numeric symbols, and to allow the formulas to be copied without changing to different cells. The average of each offerors scores was calculated to determine an average score for the subfactor using the formula

10 (a). Color Code Rating Scale

Rating Factors		Min/Max
R	1	5
Y	5	6.49
G	8	8.99
B	10	10

10 (b). Overall Subfactor Rating

Offeror	1	2	3
Factor 1 -			
Subfactor 1			
Element 1	B	G	R
	10	8	1
Element 2	G	Y	Y
	8	5	5
Average	9	6.5	3

Figure 10. Color Code Rating Scale and Overall Subfactor Rating Chart.

"=AVERAGE(E11,E13)", where the cell addresses (E11 through E13) are referenced for the range rather than using actual numbers (10, 8) to permit easy modification.

In Figure 11, factor scores were generated by calculating the average of the subfactor scores for each offeror again using the "=AVERAGE(R12:R18)" formula. Once a factor average score was derived, it was then converted back to a factor level color code using the formula:

=IF($M$2-R20>0,"R",IF($M$3-R20>0,"Y",IF($M$4-R20>0,"G","B")))

where the MIN/MAX range in Figure 10(a) was used to determine the high and low "cut off" points for each color. $M$2, $M$3, and $M$4 were cell addresses for the maximum number in the range for the colors red, yellow, and green, respectively. The formula stated if the maximum number in the cell subtracted from the factor average (R20) was greater than 0, then input that color code (R, Y, or G), otherwise the computer would

input a blue “B” rating. The range for the color code red “R” was 0-5; the range for the color code yellow “Y” was 5.01 to 6.49; the range for the color code green “G” was 6.50 to 8.99; and the range for the color code blue “B” was 9-10. The logic for this rating scale range was to permit some flexibility in rounding the average factor scores to accommodate for the loss of integrity of the data assumed when calculating an average (factor level) from an average (subfactor level).

To ensure the requirement mandated by acquisition regulations which stated if a rating of red was received at any lower level then it must be shown at the next highest level, a formula to count the number of red ratings each offeror received was incorporated into Figure 11. The formula “=COUNTIF($E$10:$E$51,"R"),” which translates “count one if a cell in the specified range is equal to ‘R’.” This would permit the team chief and SSA to know if an offeror had received any red ratings at a lower level without requiring

Average Score for Factor 1

	Offeror	1	2	3
Factor 1	Subfactor 1	B	G	R
	Element Average	9.00	6.50	3.00
	Subfactor 2	B	G	G
	Element Average	10.00	8.67	7.00
	Subfactor 3	G	G	R
	Element Average	8.67	7.67	4.67
	Subfactor 4	G	B	R
	Element Average	8.00	10.00	3.00
Factor 1 Average Score		8.92	8.21	4.42
	Factor Level Color Code	G	G	R
	Number of Red Elements	0	0	3

Figure 11. Average Score Chart for Factors.

them to search through all of the data in the worksheets. This portion of the "Average Score Chart for the Factors" was copied to the "Technical Factors" and "Final AHP Evaluation" worksheets to alert evaluators at each level that an offeror had a red rating at a lower level and could not receive award. A separate row was copied to the "Final AHP Evaluation" worksheet from the "Past Performance" worksheet to indicate the number of red ratings received on past performance.

Figure 12 is a chart from the "Technical Factors" worksheet demonstrating an AHP pairwise and a normalized matrix. An AHP matrix was constructed for each technical factor to determine a factor score for each offeror. These factor scores were used in the final AHP model to derive the overall best value offeror. To avoid re-input of the data, the factor ratings were automatically updated from the "Technical Factor

Offeror	Factor 1 Ratings
1	G
	S
2	G
	S
3	R
	1

	1	2	3	
1	1.000	1.000	7.000	
2	1.000	1.000	7.000	
3	0.143	0.143	1.000	
Sum	2.143	2.143	15.000	
	0	0	3	Number of Red

Normalized Comparisons

	1	2	3	Factor 1 Score	Consistency Measure
1	0.467	0.467	0.467	0.467	3.000
2	0.467	0.467	0.467	0.467	3.000
3	0.067	0.067	0.067	0.067	3.000

RI = 0.58 Consistency Ratio: 0.000

Figure 12. Technical Factor Pairwise and Normalized Matrices in an AHP Chart.

Ratings" worksheet using the formula "= CELL ADDRESS" (i.e. "='Technical Factor Ratings'!R21") and to calculate the value of the color code the formula:

=IF(E9="R",$K$2,IF(E9="Y",$K$3,IF(E9="G",$K$4,IF(E9="B",$K$5))))

This was the same technique as applied in Figure 10 to determine the values of the color codes. For pairwise comparisons, the formulas in the matrix to input the preferences between offerors was:

=IF((E10-E14)=0,1,IF((E10-E14)>0,(E10-E14),(1/(E14-E10))))

which stated if the value in the cell for offeror 1 minus the value in the cell for offeror 2 equals 0, then input a 1 (equal preferences); if the value in the cell for offeror 1 minus the value in the cell for offeror 2 is greater than 0, then input the difference; otherwise, input the reciprocal of the value in the cell for offeror 1 minus the value in the cell for offeror 2. The reciprocal formula "=1/I8" was input using the cell address into the cell for comparing offeror 2 to offeror 1. These formulas were copied to the appropriate cells for comparison of all offerors in each of the four factor matrices. The formulas for the normalized matrices discussed by Ragsdale (1997) were input (using cell addresses for easy editing) into the matrices to determine the factor scores and consistency ratios. These formulas include:

=SUM(G8:G10) (Sum of Offeror Columns in Pairwise Matrix)

=G8/G$11 (Normalized Matrix - i.e. first cell in column of pairwise matrix divided by the sum of the column)

=AVERAGE(G18:I18) (Factor Score - i.e. average of the cells in the first row of the normalized matrix)

=MMULT(G8:I8,$J$18:$J$20)/J18 (Consistency Measure)

=(AVERAGE(K18:K20)-3)/2/H22 (Consistency Ratio, where H22 equals the RI factor)

The RI factor used in calculating the consistency ratio was added using a cell address (H22) as a reminder to personnel that this factor may need to be changed based upon the number of "n," or offerors, being compared. Ragsdale provides a RI factor scale with a range from 2 - 8 (Table 7). In large source selections, for systems acquisitions, a maximum of n=8 would appear to suffice as it seemed apparent the number of offerors was generally less than 8.

Offeror	Rating
1	B
	10
2	G
	8
3	G
	8

	1	2	3
1	1.000	2.000	2.000
2	0.500	1.000	1.000
3	0.500	1.000	1.000
Sum	2.000	4.000	4.000

Normalized Comparisons	1	2	3	Past Performance Score	Consistency Measure
1	0.500	0.500	0.500	0.500	3.000
2	0.250	0.250	0.250	0.250	3.000
3	0.250	0.250	0.250	0.250	3.000

RI = 0.58

Consistency Ratio: 0.000

Figure 13. Past Performance Pairwise and Normalized Matrices.

To evaluate Past Performance, the same color coding concept was applied as used for developing the technical factor scores. Figure 13 demonstrates the application of the AHP pairwise and normalized matrices to rate past performance. The Past Performance

scores were automatically entered into the "Final AHP Evaluation" worksheet for final analysis.

The cost/price criterion (Figure 14) was rated using the 9-point preference scale from Table 6 (Ragsdale, 1997). The preferences are subjectively categorized based upon the ranking of the offers. In this model, it was assumed that offeror 1 had the highest price, $3,000,000; offeror 2 had the lowest price $2,500,000; and offeror 3 was in the middle range with an offer of $2,800,000. Since the difference between the highest and lowest offers was not extremely significant, a rating of 7- Very Strongly Preferred was assigned to compare the difference between offerors 2 (low) and 1 (high) because of the $500,000 difference in price. A rating of 5- Strongly Preferred was assigned to compare the difference between offerors 2 (low) and 3 (medium) because of a $300,000 difference in price. A rating of 3- Moderately Preferred was assigned to compare the difference between offerors 3 (medium) and 1 (high) because of a $200,000 difference in price. Since the reciprocal formulas were entered into the chart's cells where the row (offeror 2) intersects with column (offeror 1); row (offeror 3) intersects with column (offeror 1); and row (offeror 3) intersects with column (offeror 2), the reciprocal formulas "=1/7" and "=1/3" had to be manually entered into the cells where row (offeror 1) intersects with column (offeror 2) and row (offeror 1) intersects with column (offeror 3), respectively. This was necessary because the prices for offerors 2 and 3 were higher than offeror 1, in the comparisons of offerors 1 to 2 and 1 to 3. The number "5" was manually input into the row where (offeror 2) intersects with column (offeror 3). The reciprocal was not required in this cell because the price for offeror 2 was lower than the price for offeror 3.

The Cost/Price Scores in the normalized matrix were calculated using the formulas for the pairwise and normalized matrices given previously (paragraph 2.4.6.2).

Ranking		1	2	3
high	1	1.000	0.143	0.333
low	2	7.000	1.000	5.000
middle	3	5.000	0.200	1.000
	Sum	11.000	1.343	6.333

Normalized Comparison	1	2	3	Cost/Price Score	Consistency Measure
1	0.091	0.106	0.053	0.083	3.014
2	0.636	0.745	0.789	0.724	3.141
3	0.273	0.149	0.158	0.193	3.043
	RI = 0.58			Consistency Ratio:	0.057

Figure 14. Price/Cost Pairwise and Normalized Matrices.

Figure 15 provides a ranking scale for each factor criterion in relation to the other criterion. FAR 15-304(e) states "the solicitation shall...state, at a minimum, whether all evaluation factors other than cost or price, when combined, are--

(1) Significantly more important than cost or price;
(2) Approximately equal to cost or price; or
(3) Significantly less important than cost or price" (FAR 15-304(e))

This criterion weight matrix permitted the criterion to be ranked in order of importance based upon a 9-point preference scale (Figure 15) which was similar to Ragsdales (Table 6). In Figure 16, Factor 1 was the most important factor with Factors 2, 3, and 4 less important and following in descending order of importance. In relation to Factor 1, rated as 1, these factors were rated as "2," "3," and "4," respectively. Price and Past Performance were of equal importance but were less important than the technical

	9-Point Preference Scale
Value	Preference
1	Most Important Factor
2	Second Most Important Factor
3	Third Most Important Factor
4	Fourth Most Important Factor
5	Fifth Most Important Factor
6	Sixth Most Important Factor
7	Seventh Most Important Factor
8	Eight Most Important Factor
9	Ninth Most Important Factor
	*2 Factors of Equal Importance Receive Same Rating

Figure 15. Criterion Weights 9-Point Preference Scale for Acquisition Model.

factors so they were both ranked as "5's". Review of the normalization matrix and consistency ratio in Figure 16 indicated that the ranking procedure was an acceptable methodology. The Criterion Weights in the normalized matrix were calculated using the formulas for AHP pairwise and normalized matrices (paragraph 2.4.6.2). An RI factor of 1.24 was used because the number of offerors equated to n=6 criterion. The formula in the cell calculating the consistency ratio was modified as:

=((AVERAGE(L16:L21)-6)/5)/I22

to account for the increase in the number of "n." The criterion weights for each factor/criterion were automatically entered into the "Final AHP Worksheet" for calculation of the weighted average scores of each offeror.

Figure 17 provides the summary data used for presentation to the SSA. The scores calculated from the AHP pairwise and normalized matrices for each Technical Factor, Cost/Price and Past Performance criterion were automatically entered into the

	Factor 1	Factor 2	Factor 3	Factor 4	Price	Past Performance
Factor 1	1.000	2.000	3.000	4.000	5.000	5.000
Factor 2	0.500	1.000	2.000	3.000	4.000	4.000
Factor 3	0.333	0.500	1.000	2.000	3.000	3.000
Factor 4	0.250	0.333	0.500	1.000	2.000	2.000
Price	0.200	0.250	0.333	0.500	1.000	1.000
Past Perform.	0.200	0.250	0.333	0.500	1.000	1.000
Sum	2.483	4.333	7.167	11.000	16.000	16.000

	Normalized Comparisons Factor 1	Factor 2	Factor 3	Factor 4	Price	Past Perform	Criterion Weight	Consist. Measure
Factor 1	0.403	0.462	0.419	0.364	0.313	0.313	0.379	6.156
Factor 2	0.201	0.231	0.279	0.273	0.250	0.250	0.247	6.145
Factor 3	0.134	0.115	0.140	0.182	0.188	0.188	0.158	6.081
Factor 4	0.101	0.077	0.070	0.091	0.125	0.125	0.098	6.025
Price	0.081	0.058	0.047	0.045	0.063	0.063	0.059	6.039
Past Perform.	0.081	0.058	0.047	0.045	0.063	0.063	0.059	6.039
					RI = 1.24		Consistency Ratio:	0.013

Figure 16. Criteria Weight Scores Pairwise and Normalized Matrices.

AHP final matrix using the "=CELL ADDRESS" formula. Using the formula:

=SUMPRODUCT(E7:E12,$H$7:$H$12)

a weighted average score was calculated for each offeror. This formula multiplied the factor/criterion score for each offeror by its respective criterion weight, summed the products and computed a weighted average. The offeror with the highest weighted average was considered the offeror with the optimal solution and should have been recommended to receive award. However, before award could be made, the source selection team needed to ensure there were no deficiencies contained within the proposal with the highest score. A chart to show the number of red ratings for both technical

factors and past performance was included on the final AHP evaluation chart to indicate if detailed investigation was necessary by the source selection team. For offerors with weighted average scores which are fairly close in range, trade-off analysis should be conducted to ensure the highest score reflects the absolute best value alternative. The concept of an AHP model for use in the source selection decision-making process appears viable. The next section discusses the model quality in relation to communication, reliability, auditability, and modifiability.

Criterion	Alternative 1	Alternative 2	Alternative 3	Criterion Weights
Factor 1	0.467	0.467	0.067	0.379
Factor 2	0.333	0.333	0.333	0.247
Factor 3	0.429	0.429	0.143	0.158
Factor 4	0.429	0.429	0.143	0.098
Price	0.074	0.643	0.283	0.059
Past Performance	0.500	0.250	0.250	0.059
Weighted Average Score	0.403	0.426	0.170	1.000
Highest Weighted Average Score				0.426
Number of Red Technical Ratings	0	0	6	
Number of Red Past Performance Ratings	0	0	0	

Figure 17. Final AHP Scoring Chart.

*4.3.2.1 **Communication.*** The AFFARS Appendix AA/BB AHP model was designed using multiple worksheets to furnish top level information required by a SSA to make a decision in the first worksheet. The "Final AHP Model" worksheet provides a factor level summary, and subsequent worksheets expand the data evaluated into lower level subfactors and elements to provide detailed information. At the element level,

additional worksheets ("Subfactor Averages," "Technical Elements Summary," and "Technical Elements") were provided to demonstrate the differences between offerors for each technical subfactor at the element level. This information did not flow into the AHP model but was designed to furnish detailed information should the SSA request it.

In addition, in the "Evaluator Element Rating" worksheet, a frequency count formula was devised in the overall summary matrix to permit the team chief to compare the number of each color attributed to each element at a glance. The values of 1000, 100, 10, and 1 were assigned, respectively, to the colors red, yellow, green, and blue. If four evaluators collectively assigned 2 blue, 1 green, and 1 yellow to an offeror for a specific element, then the frequency count formula would calculate and assign a value of 0112. This communicates to the team leader on the consistency of the ratings between evaluators and permits him/her to investigate potential discrepancies and/or assign a subfactor rating based upon the individual elements scores.

Another communications tool was the consistent use of colors throughout the model to signify specific types of data. For example, award cannot be made to any offeror who has a deficiency at a lower level. To provide an audit trail, and to communicate to the SSA that an offeror's proposal had a deficiency, or "red" rating, a count of the number of red ratings was provided in red-colored cells which were placed below the overall ratings provided to the SSA. This would direct the attention of the SSA to the red cells in the spreadsheet to inform him/her if any red cells contained a number > 0, then award could not be made to that offeror.

4.3.2.2 ***Reliability.*** The consistency factors in the AHP model provided a certain level of reliability to the model. The major problem observed with the AHP model was in the use of the rating scale preferences provided by Ragsdale in Table 6. The consistency ratio was often > 0.10 when the preferences were at the higher end of the rating scale. This was noted mainly in the ranking of criterion in the "Criteria Weights" worksheet. If the preferences were subjectively assigned in the cells based on preferences, the chance for error increased as the consistency scores became extremely high. Ranking the technical factors, for example from 1-4, cost/price at 5, and past performance either 5 (equal with cost/price) or 6 (lower than cost/price), and continuing this methodology throughout the matrix resulted in consistency ratios < 0.10 and reduced the chance for error (Figure 16). To prevent errors from occurring at the element level and past performance ratings, a new standard rating scale was devised for the color codes. A "1" was assigned to all red ratings, a "5" was assigned to all yellow ratings, an "8" was assigned to all green ratings, and a "10" was assigned to all blue ratings. Once these new ratings were applied to the model, the consistency ratio normalized itself and systematically measured < 0.10 and most often 0.00.

For offerors with weighted average scores which are reasonably close in range, trade-off analysis should be conducted to ensure the highest score reflects the absolute best value alternative. Since the Technical Factor Scores are based upon averages of lower level criterion averages, some integrity of the rating data could be lost during the "roll-up" of averages Due to this fact, the proposal's of offerors that have final weighted

scores fairly proximal should be impartially reviewed to ensure all determinants have been fairly evaluated and the Government is receiving the best value alternative.

4.3.2.3 ***Auditability.*** Color coding was used in the model to assist personnel trying to audit the results of the model to understand and verify what level of information was being obtained. Factor information was turquoise, subfactor information was pink, element information was light blue. Data obtained from AHP Scores were yellow, data from averaging information was light green, data indicating the maximum or highest number within a range was light purple, and rating scales were light yellow. These were just a few examples where colors were used to permit user auditability.

Formulas (=AVERAGE('Technical Element Summary'!F8:F9)) and cell references (='Evaluator Element Ratings'!$Z$14) were used within the cell addresses rather than hard numbers to permit the efficient flow of information from one worksheet to another. If information changed on an offerors evaluation at the element level, the new data was input and the computer would automatically update the remainder of information to provide the new results at the highest level.

4.3.2.4 ***Modifiability.*** The spreadsheet was designed for flexibility in modifying the data contained in the baseline AHP model, or even to create new models through the copy and paste feature of the Microsoft Excel program. Using the "insert cells" function, the source selection team is permitted to insert additional offeror information or criterion factors into the AHP matrix without harming the data already contained in the matrix. The AHP matrices were aligned in the spreadsheet to easily add rows or columns and still maintain the integrity of the data. Formulas could be copied to

the cells for any additional offeror from existing offeror cells. AHP matrices could be copied to new worksheets with minimal editing, and no editing requirements if they were placed in the same rows and columns as on the previous worksheet. New factors, subfactors, and elements could be added in the same fashion.

The deletion of offerors from the matrix, or the deletion of factors, subfactors, and elements could be accomplished using the "delete, shift cells…" feature of the program. This feature permits information to be deleted but still maintains the integrity of the remaining data.

4.3.2.5 Limitations of the AHP Model. This model was designed with the assumption that assessment criteria, general considerations, proposal risk and performance risk would be evaluated either prior to entering color codes into the model or after the Final AHP evaluation was completed. No provisions were built into the model to assess these criteria. Excel models using matrices currently exist to conduct risk assessment so this area was not addressed in this thesis (Garvey and Lansdowne, 1998).

Changes in proposal evaluation data compiled from Best and Final Offer analysis could be easily input into the spreadsheet so the final AHP evaluation matrices could be compared to determine changes in ratings based upon reevaluation of proposals. Comparison for Best and Final Offers was not automatically built into the model. The model has potential for trade-off analysis, however changing the color codes at the element level would be necessary to obtain the necessary results. The AHP model may not be the best method for conducting trade-off-analysis.

4.3.3 FAR Part 15, Competitive Procedures. The Microsoft Excel SOLVER program using ILP was used to design the model for Competitive acquisitions, using procedures under FAR Part 15. Windows 97 was used in the development of this model. Appendix D, Figures 25 - 27 provide visual data of charts from the actual model developed. Appendix D, Table 9 provides the SOLVER parameters and options necessary to solve the ILP problem. The competitive acquisition model was designed based upon the lowest priced, technically acceptable offeror concept. Like the sealed bidding model, the model was arranged to permit the contracting official to input specific background data, and to receive some direction from the initial "Acquisition Background" worksheet. A single SOLVER model was designed to permit award of a single, or "aggregate" contract because multiple awards were unlikely. The "FAR Part 15" worksheet was copied and modified using the "Sealed Bid – Aggregate" worksheet. Data on technical acceptability was initially input by the contracting official into a factor rating chart (Figure 26) in the "Technically Acceptable" worksheet. This worksheet was copied and modified from the AFFARS Appendix AA/BB source selection AHP model. Figure 27 diagrams the rating scale and values used to determine technical acceptance of an offeror. An acceptable, or "A" rating means the proposal is accepted as submitted. A marginal, or "M" rating means the proposal was marginal but could reasonably be made acceptable through the submission of clarifying or supplemental information, through discussions, which does not substantially change the proposal information already submitted. An unacceptable, or "U" rating means the proposal is not acceptable. Using binary constraints, an acceptable rating was given a factor of "1" and a marginal and

unacceptable rating were given a factor of "0." A marginal proposal was not factored as a "1" because it would be necessary to change the "M" to an "A" and become acceptable through discussions or clarifications before it could receive award. The SSA would be required to make a determination whether or not discussions were warranted if the provision stating award can be made without discussions was included in the solicitation. The technical data was input at the element level, as in the AHP model, but was subjectively rated through the Factor level by the technical team chief. The technical factor ratings were then transferred to the "FAR Part 15"worksheet using the "=CELL ADDRESS" formula. The technical data was incorporated into the SOLVER model through the use of the binary constraints (Figure 25). As in the sealed bid model, a worksheet "Unbalanced Bids" using graphics was provided to permit analysis of offeror's proposals for indications of unbalanced proposals or front-end loaded proposals. Fill-in data from the "Unbalanced Bids" worksheet would be transferred to the "FAR Part 15" worksheet.

4.3.3.1 FAR Part 15, Model Analysis. Since the FAR Part 15 model was created by modifying the sealed bid model for the SOLVER input and the AHP model for the technical data, the discussion on communication, reliability, auditability, modifiability, and model limitations were the same as in the sealed bidding and in some of the AHP technical portions of the previous sections. This model would have the same reliability concerns as the sealed bid model, due to the use of the SOLVER program. However, the technical data in this model was not "rolled up" using averages as in the AHP pairwise model. The technical factors were manually evaluated by the contracting official who had

to subjectively assign a higher rating based upon the information provided at the lower levels. Pairwise matrices were not used for analysis in this model.

4.4 Conclusion

Chapter 4 has answered the investigative questions first discussed in Chapter 1 of this thesis. A schematic model of information technology was designed, and represents one of many solutions, incorporating information technology into the source selection decision-making process. Three decision-making models were designed and developed using the Microsoft Excel spreadsheets program. Two of the models (sealed bids and competitive procedures, FAR Part 15) used the SOLVER option program, and one (AFFARS Appendix AA/BB) used the Analytical Hierarchy Process. The SOLVER program was not used on the AFFARS Appendix AA/BB source selection model since the AHP model was the preferred approach. Due to the enormous size of the models, it was impossible to provide complete copies of the model within the text of this document. As much information was provided to permit the reader to visualize the basic concepts of the models and to understand the textual discussions within this document.

Chapter 5 discusses the overall summary of the research and provides recommendations based upon the findings summarized.

5. Summary and Recommendations

5.1 Introduction

Decision-making in a source selection, whether it be a large scale source selection as in using AFFARS Appendix AA/BB procedures or a smaller scale using sealed bidding or competitive procurement procedures, is an important aspect of whether the AF and the Government successfully perform their mission. The increase of outsourcing work to contracted sources makes good decision-making in the evaluation of offerors imperative to permit the AF to meet its requirements within its budget constraints. The information technology systems discussed in this research could enhance the SSA's ability to make better decisions in a more efficient manner.

5.2 Summary Review of the Research

5.2.1 Investigative Question Number One. Can a schematic model be designed to identify areas where information technology can improve the flow of information into the source selection evaluation process and expand the present tactical approach to evaluation of alternatives into a more strategic approach?

5.2.1.1 Findings and Recommendations.

1. A schematic information technology model was designed and the technology exists to realize this information system. This information system has the potential to transform the acquisition community into a more strategic, proactive component within the AF and Government, as a whole. The next step prior to development and implementation of an application model would be to analyze and evaluate application

models, such as a DSS or ES, which are currently operating in a business decision-making environment. Evaluation and comparison of the hardware, software, and other information technology components used in the development and operation of these types of systems prior to development could permit a more efficient and effective system design to be implemented within the acquisition field. Operational analysis of systems currently in use would permit contracting officials to evaluate the functionality of a DSS system and its components to determine if the schematic model designed in this research is the best solution. Analysis of various systems in operation would permit a comparison of system application with the literature to determine if the systems could actually function as the literature claims or if modification of the system would be required.

2. The Government acquisition field is unique with its numerous policies, laws, and regulations. Decision support systems developed for use for commercial acquisitions would not contain many of the constraints or restrictions placed upon the Government within their systems. Modification of these systems would be necessary prior to implementation in the Government acquisition field. Should a commercial system be selected for implementation, it is recommended it be reviewed for flexibility and adaptability to incorporate the required modifications at the lowest possible cost. This requirement became apparent during the development of the AHP evaluation model for AFFARS Appendix AA/BB source selections. Much of the literature reviewed recommended the use of AHP techniques for the design and development of a source selection model because it could incorporate the qualitative data resulting from evaluation of technical and past performance criteria. However, actual implementation of the model

revealed slight modification was necessary due to the Government requirement which restricts comparison of offerors against their competitors.

3. Depending upon the type of model base implemented in the schematic model, a better user interface device should be explored to permit contracting officials to easily develop models for each new acquisition. The user interface device should permit the automatic generation of models based upon a specific acquisition situation. It should also permit the automatic generation of reports and sensitivity analysis to determine how changes in constraints affect the results of the selection. Further research might be conducted in the use of Visual Basic for Applications (VBA) (Hill, 1998) and how it could be incorporated into the SPS system to permit the automatic model generation.

5.2.2 Investigative Question Number Two. Can a baseline model be designed, based upon Microsoft Excel SOLVER, to assist the SSA in choosing the optimal or best alternative source in a competitive source selection?

5.2.2.1 Findings and Recommendations.

1. The use of Management Science techniques, such as ILP and AHP, in the design and development of a decision-making model base can be successfully accomplished using spreadsheet design. Three evaluation models were developed using ILP or AHP techniques which accurately provided a best alternative solution based upon the criteria and constraints for the problem. However, verification of the models was conducted on a very limited basis. Further analysis using test cases of actual contract data should be conducted to validate the use of the spreadsheet-based models to evaluate

acquisition data. The model's ability to generate accurate and reliable solutions consistently needs to be assessed and validated prior to implementation.

2. One problem noted during development resulted from consistent reliability when using the ILP models utilizing the Microsoft Excel SOLVER program. The ILP models performed as expected and initially solved the problems correctly, but an occasional loss of reliability occurred when minor changes, such as offered price, were implemented in the problem. This loss led to a concern regarding the reliability of solutions generated in the SOLVER program, and more so when the acquisition problem became so extensive that manual verification could not be easily accomplished. Acquisition data, such as prices and technical constraints, are often modified based upon discussions during a source selection and the contracting official must ensure the evaluation method used, whether a computer or manual manipulation, can reliably accommodate and adapt for these changes. Two recommendations for further investigation are recommended as a result of the reliability problem. First, examination of the model's formulation to determine if it is too sensitive for use by Excel's SOLVER program. This sensitivity could result in the occasional unreliability seen during the initial development. Second, a recommendation to explore other Frontline SOLVER and spreadsheet model software programs to determine if other software has more reliable capabilities to incorporate changes.

3. The AHP model was reliable in consistently generating accurate solutions but the averaging of average evaluation scores from lower levels of evaluation might be considered a protestable issue to an offeror losing the award to another contractor. To

deter protests, further research would be necessary to analyze and develop standard coding systems for rating conversion (i.e. B = 10, G = 8, Y = 5, R = 1) for use in the AHP model. A standard coding system would provide consistency among contracting officials permit a more objective evaluation because the numeric standard rating for a qualitative color or adjectival ratings would remain unchanged from acquisition to acquisition.

4. The extent of training and educating personnel in the acquisition field to use the management science tools for optimization in decision-making, the use, capabilities, and limitations of programs such as Microsoft Excel SOLVER and the AHP pairwise matrices, and to comprehend and obtain the mathematical (i.e. linear functions and matrices) and computer (spreadsheet capabilities) could be another deterrent from implementation of the use of management science tools in the evaluation process. These skills and knowledge are required to design and development an evaluation model. A study could be conducted to examine the knowledge and skill levels of contracting professionals and a determination could be made on the amount of training to implement. Another recommendation to avoid extensive training of personnel in advanced mathematics and computer knowledge would be to include Operations Research personnel on teams to design the information systems for the procurement field. The DoD Standard Procurement System, currently in development, could be designed to incorporate user-friendly evaluation models to permit the computer to develop the models based upon data entered and responses obtained from contracting officials. A user friendly interface could prevent the need for detailed training. In addition, a study to analyze potential constraints contained within the acquisition

regulations could be accomplished and a manual developed to instruct personnel on the procedure to input these constraints into the optimization program. These would also reduce the amount of training necessary for personnel to implement management science tools in the evaluation process of a source selection.

5. Different types of acquisitions require the use of different types of evaluation tools. A sealed bid acquisition restricted to an aggregate award, with a small number of CLIN and offerors, could easily be evaluated using a basic spreadsheet to calculate the total price of each offeror. The use of the SOLVER program would not benefit the evaluation process in an acquisition of this type. However, for larger acquisitions which permit multiple awards or have numerous constraints, offerors, and CLINs, the development of a model using a SOLVER program could prove beneficial. The AHP model is effective in determining best value for Appendix BB source selection but other models, such as an optimization model, should be explored as a viable method of solving these decision problems. The main point is to use the right tool for job.

6. Once a model becomes too large, spreadsheet tools become difficult to manage. This became very evident during model development and analysis. Due to this difficulty, it is recommended that other information technology tools be investigated for potential use as the model base in the schematic DSS model resulting from investigative question one. On their internet website, Compass Modeling Solutions advertises a large-scale linear programming/mixed integer programming (LP/MIP) SOLVER from Frontline which has the capacity to "solve problems with up to 6,500 variables, and to upgrade the Microsoft Excel SOLVER program to make it significantly faster and more robust." Compass

claims the capabilities of the spreadsheet programs such as Microsoft Excel and Borland's Quattro Pro, which are sold with integrated optimizers, are limited. Compass claims the Microsoft Excel SOLVER program can only solve linear programs with less than 200 variables and 100 constraints (Compass, 1998).

IBM Manufacturing Solutions advertises "IBM Application Development tools as the basis for solving many types of linear programming, mixed integer programming, as well as other intelligent heuristic and solver techniques" (IBM, 1998). Two specific tools advertised by IBM include an Optimization Subroutine Library and a Mathematical Programming Systems Extended (MPSX) program. The Optimization Subroutine Library is "a suite of subroutines for manipulating models and solving the resulting minimization problems of mathematical optimization" (IBM, 1998). The library includes solvers for linear programming, quadratic programming, and mixed integer programming. The MPSX is a "decision sciences tool that is used to make better business decisions [by using] advanced linear and mixed integer programming to analyze complex business environments to select the best course of action among many feasible alternatives (IBM, 1998). Many software programs exist to implement management science tools efficiently and effectively. Prior to design and implementation of a standard evaluation tool in the acquisition field, examination of the various software programs should be conducted to ensure consistent accuracy and reliability of each model.

5.3 Conclusion

In conclusion, the results of the research proved to re-enforce the need for the Government to develop information technology systems using more strategic decision-

making methods, such as found in the field of management science. Expert Systems using artificial intelligence, Decision Support Systems using "if-then" statements or case based reasoning, and evaluation models implementing integer linear programming or analytical hierarchy processes are just some of the tools provided through management science which can enhance the decision-making ability of the SSA in determining the best alternative to the Government.

APPENDIX A. FAR 15-304

(a) The award decision is based on evaluation factors and significant subfactors that are tailored to the acquisition.

(b) Evaluation factors and significant subfactors must--

(1) Represent the key areas of importance and emphasis to be considered in the source selection decision; and

(2) Support meaningful comparison and discrimination between and among competing proposals.

(c) The evaluation factors and significant subfactors that apply to an acquisition and their relative importance are within the broad discretion of agency acquisition officials, subject to the following requirements:

(1) Price or cost to the Government shall be evaluated in every source selection (10 U.S.C. 2305(a)(3)(A) (ii) and 41 U.S.C. 253a(c)(1)(B));

(2) The quality of the product or service shall be addressed in every source selection through consideration of one or more non-cost evaluation factors such as past performance, compliance with solicitation requirements, technical excellence, management capability, personnel qualifications, and prior experience (10 U.S.C. 2305(a)(3)(A)(i) and 41 U.S.C. 253a(c)(1)(A)); and **[DoD Deviation 97-00009]**

> **(3)(i) Except as set forth in paragraph (c)(3)(iii) of this section, past performance shall be evaluated in all source selections for negotiated competitive acquisitions expected to exceed $5,000,000 for Systems and Operations Support or expected to exceed $1,000,000 for all other acquisitions.**
>
> **(ii) Past performance need not be evaluated if the contracting officer documents the reason past performance is not an appropriate evaluation factor for the acquisition (OFPP Policy Letter 92-5). [SIC]**

(3)(i) Except as set forth in paragraph (c)(3)(iii) of this section, past performance shall be evaluated in all source selections for negotiated competitive acquisitions expected to exceed $1,000,000.

(ii) Except as set forth in paragraph (c)(3)(iii) of this section, past performance shall be evaluated in all source selections for negotiated competitive acquisitions issued on or after January 1, 1999, for acquisitions expected to exceed $100,000. Agencies should develop phase-in schedules that meet or exceed this schedule.

(iii) Past performance need not be evaluated if the contracting officer documents the reason past performance is not an appropriate evaluation factor for the acquisition.

(d) All factors and significant subfactors that will affect contract award and their relative importance shall be stated clearly in the solicitation (10 U.S.C. 2305(a)(2)(A)(i) and 41 U.S.C. 253a(b)(1)(A)).

The rating method need not be disclosed in the solicitation.
The general approach for evaluating past performance information shall be described.

(e) The solicitation shall also state, at a minimum, whether all evaluation factors other than cost or price, when combined, are--

(1) Significantly more important than cost or price;

(2) Approximately equal to cost or price; or

(3) Significantly less important than cost or price (10 U.S.C. 2305(a)(3)(A)(iii) and 41 U.S.C. 253a(c)(1)(C)).

Appendix B. A Contract Award Problem
(Ragsdale, 1997: 234-241)

Sample Problem--Integer Linear Programming:

B&G Construction is a commercial building company located in Tampa, Florida. The Company has recently signed contracts to construct four buildings in different locations throughout southern Florida. Each building project requires large amounts of cement to be delivered to the building sites. At B&G's request, three cement companies have submitted bids for supplying the cement for these jobs. The following table summarizes the prices the three companies charge per delivered ton of cement and the maximum amount of cement that each company can provide.

	Cost Per Delivered Ton of Cement				
	Project 1	**Project 2**	**Project 3**	**Project 4**	**Max. Supply**
Company 1	**$120**	**$115**	**$130**	**$125**	**525**
Company 2	**$100**	**$150**	**$110**	**$105**	**450**
Company 3	**$140**	**$95**	**$145**	**$165**	**550**
Total Tons Needed	**450**	**275**	**300**	**350**	

For example, company 1 can supply a maximum of 525 tons of cement, and each ton delivered to projects 1, 2, 3, and 4 will cost $120, $115, $130, and $125, respectively. The costs vary primarily because of the different distances between the cement plants and the construction sites. The numbers in the last row of the table indicate the total amount of cement (in tons) required for each project.

In addition to the maximum supplies listed, each cement company places special conditions on its bid. Specifically, company 1 indicated that it will not supply orders of less than 150 tons for any of the construction projects. Company 2 indicated that it can supply more than 200 tons to no more than one of the projects. Company 3 indicated that it will accept only orders that total 200 tons, 400 tons, or 550 tons.

B&G can contract with no more than one supplier to meet the cement requirements for a given project. The problem is to determine what amounts to purchase from each supplier to meet the demands for each project at the least total cost.

---

1). To begin formulating this problem, first define the decision variables as:

X_{ij} = tons of cement purchased from company i for construction project j

2). Establish the objective function to minimize total cost as:

$$\begin{aligned}\text{MIN: } & 120X_{11} + 115X_{12} + 130X_{13} + 125X_{14} \\ & + 100X_{21} + 150X_{22} + 110X_{23} + 105X_{24} \\ & + 140X_{31} + 95X_{32} + 145X_{33} + 165X_{34}\end{aligned}$$

3). Establish the constraints to ensure the maximum supply of cement from each company is not exceeded:

$$\begin{aligned}X_{11} + X_{12} + X_{13} + X_{14} &\leq 525 \quad \} \text{ supply from company 1} \\ X_{21} + X_{22} + X_{23} + X_{24} &\leq 450 \quad \} \text{ supply from company 2} \\ X_{31} + X_{32} + X_{33} + X_{34} &\leq 550 \quad \} \text{ supply from company 3}\end{aligned}$$

4). Establish the constraints to ensure the requirements for cement at each construction project are met:

$$\begin{aligned}X_{11} + X_{21} + X_{31} &= 450 \quad \} \text{ demand for cement at project 1} \\ X_{12} + X_{22} + X_{32} &= 275 \quad \} \text{ demand for cement at project 2} \\ X_{13} + X_{23} + X_{33} &= 300 \quad \} \text{ demand for cement at project 3} \\ X_{14} + X_{24} + X_{34} &= 350 \quad \} \text{ demand for cement at project 4}\end{aligned}$$

5). Figure 6 demonstrates how the objective function and constraints of this problems are implemented into a spreadsheet model. In this spreadsheet, the costs per delivered ton of cement are shown in cells B3 through E5. Cells B9 through E11 represent the decision variables in the model. The objective function is entered in cell G13 as:

Formula for cell G13: =SUMPRODUCT (B3:E5,B9:E11)

The left-hand side (LHS) formulas of the supply constraints are entered in cells F9 through F11 as:

Formula for cell F9: =SUM(B9:E9)
(Copy to F10 through F11)

Cells G9 through G11 contain the right-hand side (RHS) values for these constraints. The LHS formulas for the demand constraints are entered in cells B12 through E12 as:

Formula for cell B12: =SUM(B9:B11)
(Copy to C12 through E12)

Cells B13 through E13 contain the RHS values for these constraints.

6). Formulate the side-constraints. Company 1 indicated that it will not accept orders for less than 150 tons for any of the construction projects. This minimum order-size restriction is modeled by the following eight constraints, where Y_{ij} represent binary variables:

$X_{11} \leq 525Y_{11}$
$X_{12} \leq 525Y_{12}$
$X_{13} \leq 525Y_{13}$
$X_{14} \leq 525Y_{14}$
$X_{11} \geq 525Y_{11}$
$X_{12} \geq 525Y_{12}$
$X_{13} \geq 525Y_{13}$
$X_{14} \geq 525Y_{14}$

Each constraint has an algebraically equivalent constraint, which will ultimately be used in implementing the constraint in the spreadsheet. The first four constraints represent linking constraints that ensure if X_{11}, X_{12}, X_{13}, or X_{14} is greater than 0, then its associated binary variable (Y_{11}, Y_{12}, Y_{13}, or Y_{14}) must be equal to 1. (These constraints also indicate that 525 is the maximum value that can be assumed by X_{11}, X_{12}, X_{13}, and X_{14}). The next four constraints ensure that if X_{11}, X_{12}, X_{13}, or X_{14} is greater than 0, it must be at least 150. These constraints are included in the model to ensure that any order given to company 1 is for at least 150 tons of cement.

Company 2 indicated that it can supply more than 200 tons to no more than one of the projects. This type of restriction is represented by the following set of constraints where the Y_{ij} represent binary variables:

$X_{21} \leq 200 + 250Y_{21}$ (implement as $X_{21} - 200 - 250Y_{21} \leq 0$)
$X_{22} \leq 200 + 250Y_{22}$ (implement as $X_{22} - 200 - 250Y_{22} \leq 0$)
$X_{23} \leq 200 + 250Y_{23}$ (implement as $X_{23} - 200 - 250Y_{23} \leq 0$)
$X_{24} \leq 200 + 250Y_{24}$ (implement as $X_{24} - 200 - 250Y_{24} \leq 0$)
$Y_{21} + Y_{22} + Y_{23} + Y_{24} \leq 1$ (implement as is)

The first constraint indicates that the amount supplied from company 2 for project 1 must be less than 200 if $Y_{21} = 0$, or less than 450 (the maximum supply form company 2) if $Y_{21} = 1$. The next three constraints have similar interpretations for the amount supplied from company 2 to projects 2, 3, and 4, respectively. The last constraint indicates that at most one of Y_{21}, Y_{22}, Y_{23}, and Y_{24} can equal 1. Therefore, only one of the projects can receive more than 200 tons of cement from company 2.

The final set of constraints for this problem addresses company 3's stipulation that it will accept only orders totaling 200, 400, or 550 tons. This type of condition is modeled using binary Y_{ij} variables as:

$X_{31} + X_{32} + X_{33} + X_{34} = 200Y_{31} + 400Y_{32} + 550Y_{33}$
(implement as $X_{31} + X_{32} + X_{33} + X_{34} - 200Y_{31} - 400Y_{32} - 550Y_{33} = 0$)
$Y_{31} + Y_{32} + Y_{33} \leq 1$ (implement as is)

These constraints allow for the total amount ordered from company 3 to assume four distinct values. If $Y_{31} = Y_{32} = Y_{33} = 0$, then no cement will be ordered from company 3. If $Y_{31} = 1$, then 200 tons must be ordered. If $Y_{32} = 1$, then 400 tons must be ordered. Finally, if $Y_{33} = 1$, then 550 tons must be ordered from company 3. These two constraints enforce the special condition imposed by company 3.

7). Figure 18 demonstrates how the side-constraints are implemented into a spreadsheet model. The side-constraints in this problem impose restrictions on the feasible solutions that can be considered, but these constraints serve a more "mechanical" purpose—to make the model work—and are not of primary interest to management. As such, it is often convenient to implement side-constraints in an out-of-the-way area of the spreadsheet so they do not detract from the primary purpose of the spreadsheet.

To implement the side-constraints for company 1, we enter a batch-size restriction of 150 in cell B17 and reserve cells B18 through E18 to represent the binary variables Y_{11}, Y_{12}, Y_{13}, and Y_{14}. The LHS formulas for the linking constraints for company 1 are implemented in cells B19 through E19 as:

Formula for cell B19: =B9-$G$9*B18
(Copy to C19 through E19)

Cell F19 contains a reminder to tell SOLVER that these cells must be less than or equal to 0. The LHS formulas for the batch-size constraints for company 1 are implemented in cells B20 through E20 as:

Formula for cell B20: =B9-$B$17*B18
(Copy to C20 through E20)

Cell F20 contains a reminder to tell SOLVER that these cells must be greater than or equal to 0.

To implement the side-constraints for company 2, the maximum supply value of 200 is entered in cell B22 and reserve cells B23 through E23 to represent binary variables Y_{21}, Y_{22}, Y_{23}, and Y_{24}. The LHS formulas for the maximum supply constraints are implemented in cells B24 through E24 as:

Formula for cell B24: =B10-$B$22-($G$10-$B$22)*B23
(Copy to C24 through E24)

Cell F24 contains a reminder to tell SOLVER that these cells must be less than or equal to 0. To ensure that no more than one order from company 2 exceeds 200 tons, the sum of the binary variable for company 2 cannot exceed 1. The LHS formula for this constraint is entered in cell E25 as:

Formula for cell E25: =SUM(B23:E23)

Cell F25 contains a reminder to tell SOLVER that this cell must be less than or equal to 1.

To implement the side-constraints for company 3, the three possible total order amounts are entered in cells B27 through D27. Cells B28 through D28 are reserved to represent the binary variables Y_{31}, Y_{32}, and Y_{33}. The LHS formula for company 3's total supply side-constraint is entered in cell D29 as:

Formula for cell D29: =SUM(B11:E11)-SUMPRODUCT(B27:D27,B28:D28)

Cell E29 contains a reminder to tell SOLVER that cell D29 must equal 0. To ensure that no more than one of the binary variables for company 3 is set equal to 1, the sum of these variables is entered in cell D30 as:

Formula for cell D30: =SUM(B28:D28)

Cell E30 contains a reminder to tell SOLVER that this cell must be less than or equal to 1

	A	B	C	D	E	F	G
1		Cost Per Delivered Ton					
2		Project 1	Project 2	Project 3	Project 4		
3	Company 1	$120	$115	$130	$125		
4	Company 2	$100	$150	$110	$105		
5	Company 3	$140	$95	$145	$165		
6							
7		Amount to Purchase					
8		Project 1	Project 2	Project 3	Project 4	Supplied	Available
9	Company 1	0	0	0	0	0	525
10	Company 2	0	0	0	0	0	450
11	Company 3	0	0	0	0	0	550
12	Received	0	0	0	0		
13	Needed	450	275	300	350		
14						Total Cost:	$0
15	Additional Constraints Follow:						
16							
17	Co. 1 Batch-Size	150					
18	Binary Variables	0	0	0	0		
19	Linking Constraints	0	0	0	0	(<= 0)	
20	Batch Constraints	0	0	0	0	(>= 0)	
21							
22	Co. 2 Max Supply	200					
23	Binary Variables	0	0	0	0		
24	UB Constraints	-200	-200	-200	-200	(<= 0)	
25	Sum of Binary Variables				0	(<= 1)	
26							
27	Co. 3 Tot. Supply	200	400	550			
28	Binary Variables	0	0	0			
29	Tot. Supply = 0, 200, 400, 550			0.00	(=0)		
30	Sum of Binary Variables			0	(<=1)		

Figure 18. Objective Function and Constraints Implemented in a Spreadsheet Model.

8). Solving the model. The SOLVER parameters and options required to complete this program are as follows:

SOLVER PARAMETERS

Set Target Cell:	G14
Equal to:	Min
By Changing Cells:	B9:E11, B18:E18, B23:E23, B28:D28
Subject to the Constraints:	
	B9:E11 $\geq$ 0
	B18:E18 $\geq$ 0
	B18:E18 $\leq$ 1
	B18:E18 = integer
	B23:E23 $\geq$ 0
	B23:E23 $\leq$ 1
	B23:E23 = integer
	B28:E28 $\geq$ 0
	B28:E28 $\leq$ 1
	B28:E28 = integer
	F9:F11 $\leq$ G9:G11
	B12:E12 = B13:E13
	B19:E19 $\leq$ 0
	B20:E20 $\geq$ 0
	B24:E24 $\leq$ 0
	E25 $\leq$ 1
	D29 = 0
	D30 $\leq$ 1

SOLVER OPTIONS

Assume Linear Model	Tolerance = 0%
Use Automatic Scaling	Iterations = 100

9). An optimal solution is demonstrated in Figure 19. (There are alternative optimal solutions to this problem.) In this solution, the amounts of cement required by each construction project are met exactly. Also, each condition imposed by the side-constraints for each company is met. Specifically, the orders awarded to company 1 are for at least 150 tons; only one of the orders awarded to company 2 exceeds 200 tons; and the sum of the orders awarded to company 3 is exactly equal to 400 tons.

	A	B	C	D	E	F	G
1				Cost Per Delivered Ton			
2		Project 1	Project 2	Project 3	Project 4		
3	Company 1	$120	$115	$130	$125		
4	Company 2	$100	$150	$110	$105		
5	Company 3	$140	$95	$145	$165		
6							
7				Amount to Purchase			
8		Project 1	Project 2	Project 3	Project 4	Supplied	Available
9	Company 1	175	0	0	350	525	525
10	Company 2	275	0	175	0	450	450
11	Company 3	0	275	125	0	400	550
12	Received	450	275	300	350		
13	Needed	450	275	300	350		
14						Total Cost:	$155,750
15	Additional Constraints Follow:						
16							
17	Co. 1 Batch-Size	150					
18	Binary Variables	1	0	0	1		
19	Linking Constraints	-350	0	3.23E-10	-175	(<= 0)	
20	Batch Constraints	25	0	3.23E-10	200	(>= 0)	
21							
22	Co. 2 Max Supply	200					
23	Binary Variables	1	0	0	0		
24	UB Constraints	-175	-200	-25	-200	(<= 0)	
25	Sum of Binary Variables				1	(<= 1)	
26							
27	Co. 3 Tot. Supply	200	400	550			
28	Binary Variables	0	1	0			
29	Tot. Supply = 0, 200, 400, 550			0.00	(=0)		
30	Sum of Binary Variables			1	(<=1)		

Figure 19. Optimal Solution to B&G's Contract Award Problem.

10). A Microsoft Excel Answer Summary Report is provided on the next four pages. This summary report synopsizes the final values for the target and adjustable cells. In addition, it indicates which constraints are binding or non-binding on the final solution and also reports how much slack is left in the variable, or how much the final value for that constraint can change before it affects outcome of the final solution. This report is automatically generated and can be provided to management as a summary of the problem's solution.

Microsoft Excel 7.0 Answer Report
Worksheet: Cement Contract Report

Target Cell (Min)

Cell	Name	Original Value	Final Value
$G$14	Total Cost: Available	$0	$155,750

Adjustable Cells

Cell	Name	Original Value	Final Value
$B$9	Company 1 Project 1	0	175
$C$9	Company 1 Project 2	0	0
$D$9	Company 1 Project 3	0	0
$E$9	Company 1 Project 4	0	350
$B$10	Company 2 Project 1	0	275
$C$10	Company 2 Project 2	0	0
$D$10	Company 2 Project 3	0	175
$E$10	Company 2 Project 4	0	0
$B$11	Company 3 Project 1	0	0
$C$11	Company 3 Project 2	0	275
$D$11	Company 3 Project 3	0	125
$E$11	Company 3 Project 4	0	0
$B$18	Binary Variables Project 1	0	1
$C$18	Binary Variables Project 2	0	0
$D$18	Binary Variables Project 3	0	0
$E$18	Binary Variables Project 4	0	1
$B$23	Binary Variables Project 1	0	1

	(Continued from Previous Page)		
$C$23	Binary Variables Project 2	0	0
$D$23	Binary Variables Project 3	0	0
$E$23	Binary Variables Project 4	0	0
$B$28	Binary Variables Project 1	0	0
$C$28	Binary Variables Project 2	0	1
$D$28	Binary Variables Project 3	0	0

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$F$9	Company 1 Supplied	525	$F$9<=$G$9	Binding	0
$F$10	Company 2 Supplied	450	$F$10<=$G$10	Binding	0
$F$11	Company 3 Supplied	400	$F$11<=$G$11	Not Binding	150
$B$12	Received Project 1	450	$B$12=$B$13	Binding	0
$C$12	Received Project 2	275	$C$12=$C$13	Binding	0
$D$12	Received Project 3	300	$D$12=$D$13	Binding	0
$E$12	Received Project 4	350	$E$13=$E$13	Binding	0
$B$19	Linking Constraints Project 1	-350	$B$19<=0	Not Binding	350
$C$19	Linking Constraints Project 2	3.06615E-14	$C$19<=0	Binding	0
$D$19	Linking Constraints Project 3	1.4968E-14	$D$19<=0	Binding	0
$E$19	Linking Constraints Project 4	-175	$E$19<=0	Not Binding	175
$B$20	Batch Constraints Project 1	25	$B$20>=0	Not Binding	25
$C$20	Batch Constraints Project 2	-1.17071E-14	$C$20>=0	Binding	0
$D$20	Batch Constraints Project 3	2.41024E-14	$D$20>=0	Binding	0
$E$20	Batch Constraints Project 4	200	$E$20>=0	Not Binding	200
$B$24	UB Constraints Project 1	-175	$B$24<=0	Not Binding	175
$C$24	UB Constraints Project 2	-200	$C$24<=0	Not Binding	200
$D$24	UB Constraints Project 3	-25	$D$24<=0	Not Binding	25

(Continued from Previous Page)

$E$24	UB Constraints Project 4	-200	$E$24<=0	Not Binding	200
$F$25	Sum of Binary Variables Project 4	1	$F$25<=1	Binding	0
$E$29	Tot. Supply = 0, 200, 400, 550 Project 3	0.00	$E$29=0	Binding	0.00
$E$30	Sum of Binary Variables Project 3	1	$E$30<=1	Binding	0
$B$9	Company 1 Project 1	175	$B$9>=0	Not Binding	175
$C$9	Company 1 Project 2	0	$C$9>=0	Binding	0
$D$9	Company 1 Project 3	0	$D$9>=0	Binding	0
$E$9	Company 1 Project 4	350	$E$9>=0	Not Binding	350
$B$10	Company 2 Project 1	275	$B$10>=0	Not Binding	275
$C$10	Company 2 Project 2	0	$C$10>=0	Binding	0
$D$10	Company 2 Project 3	175	$D$10>=0	Not Binding	175
$E$10	Company 2 Project 4	0	$E$10>=0	Binding	0
$B$11	Company 3 Project 1	0	$B$11>=0	Binding	0
$C$11	Company 3 Project 2	275	$C$11>=0	Not Binding	275
$D$11	Company 3 Project 3	125	$D$11>=0	Not Binding	125
$E$11	Company 3 Project 4	0	$E$11>=0	Binding	0
$B$18	Binary Variables Project 1	1	$B$18>=0	Not Binding	1
$C$18	Binary Variables Project 2	0	$C$18>=0	Binding	0
$D$18	Binary Variables Project 3	0	$D$18>=0	Binding	0
$E$18	Binary Variables Project 4	1	$E$18>=0	Not Binding	1
$B$18	Binary Variables Project 1	1	$B$18<=1	Binding	0
$C$18	Binary Variables Project 2	0	$C$18<=1	Not Binding	1
$D$18	Binary Variables Project 3	0	$D$18<=1	Not Binding	1
$E$18	Binary Variables Project 4	1	$E$18<=1	Binding	0
$B$18	Binary Variables Project 1	1	$B$18=integ	Binding	0
$C$18	Binary Variables Project 2	0	$C$18=integ	Binding	0
$D$18	Binary Variables Project 3	0	$D$18=integ	Binding	0

(Continued from Previous Page)

$E$18	Binary Variables Project 4	1	$E$18=integ	Binding	0
$B$23	Binary Variables Project 1	1	$B$23>=0	Not Binding	1
$C$23	Binary Variables Project 2	0	$C$23>=0	Binding	0
$D$23	Binary Variables Project 3	0	$D$23>=0	Binding	0
$E$23	Binary Variables Project 4	0	$E$23>=0	Binding	0
$B$23	Binary Variables Project 1	1	$B$23<=1	Binding	0
$C$23	Binary Variables Project 2	0	$C$23<=1	Not Binding	1
$D$23	Binary Variables Project 3	0	$D$23<=1	Not Binding	1
$E$23	Binary Variables Project 4	0	$E$23<=1	Not Binding	1
$B$23	Binary Variables Project 1	1	$B$23=integ	Binding	0
$C$23	Binary Variables Project 2	0	$C$23=integ	Binding	0
$D$23	Binary Variables Project 3	0	$D$23=integ	Binding	0
$E$23	Binary Variables Project 4	0	$E$23=integ	Binding	0
$B$28	Binary Variables Project 1	0	$B$28>=0	Binding	0
$C$28	Binary Variables Project 2	1	$C$28>=0	Not Binding	1
$D$28	Binary Variables Project 3	0	$D$28>=0	Binding	0
$B$28	Binary Variables Project 1	0	$B$28<=1	Not Binding	1
$C$28	Binary Variables Project 2	1	$C$28<=1	Binding	0
$D$28	Binary Variables Project 3	0	$D$28<=1	Not Binding	1
$B$28	Binary Variables Project 1	0	$B$28=integ	Binding	0
$C$28	Binary Variables Project 2	1	$C$28=integ	Binding	0
$D$28	Binary Variables Project 3	0	$D$28=integ	Binding	0

Note: With written permission from Dr. Ragsdale, the B&G Contract Award sample in Appendix B was copied from Ragsdale's Spreadsheet Modeling and Decision Analysis book. Some minor formatting revisions were incorporated but the sample content remains the same.

Appendix C. Sealed Bidding SOLVER Model

Price Offered Per CLIN

Price	Offeror 1	Offeror 2	Offeror 3	Offeror 4	Offeror 5	Offeror 6
CLIN 0001	$120	$100	$140	$130	$150	$110
CLIN 0002	$115	$150	$95	$134	$146	$121
CLIN 0003	$130	$110	$145	$115	$154	$109
CLIN 0004	$125	$105	$165	$120	$167	$117
Gov't Estimate	$125	$108	$138	$126	$160	$113

Quantity Offered Per CLIN

Quantity	Offeror 1	Offeror 2	Offeror 3	Offeror 4	Offeror 5	Offeror 6
CLIN 0001	0	0	0	0	0	0
CLIN 0002	0	0	0	0	0	0
CLIN 0003	0	0	0	0	0	0
CLIN 0004	0	0	0	0	0	0
Total Price	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00

Figure 20. Basic Sealed Bid Model Layout (Aggregate Award - Part 1).

Binary Variables

Binary Variables	Offeror 1	Offeror 2	Offeror 3	Offeror 4	Offeror 5	Offeror 6
CLIN 0001	0	0	0	0	0	0
CLIN 0002	0	0	0	0	0	0
CLIN 0003	0	0	0	0	0	0
CLIN 0004	0	0	0	0	0	0
Total	0	0	0	0	0	0

Binary: Contractor Used	0	0	0	0	0	0

Linking Variables

Linking Variables	Offeror 1	Offeror 2	Offeror 3	Offeror 4	Offeror 5	Offeror 6
CLIN 0001	0	0	0	0	0	0
CLIN 0002	0	0	0	0	0	0
CLIN 0003	0	0	0	0	0	0
CLIN 0004	0	0	0	0	0	0

Link: Used	0	0	0	0	0	0

Figure 21. Basic Sealed Bid Model Layout (Aggregate Award - Part 2).

	Offeror 6
$150	$110
$146	$121
$154	$109
$167	$117
$160	$113

Offeror 5	Offeror 6	Total QTY	QTY Required
0	0	0	450
0	0	0	275
0	0	0	300
0	0	0	350
$0.00	$0.00	$0.00	Total Price

Offeror 5	Offeror 6	Sum of Binary	
0	0	0	Sum (=1)
0	0	0	
0	0	0	
0	0	0	
0	0		
		Sum of Binary: Used	
0	0	0	Sum Used (<=1)

Offeror 5	Offeror 6	MAX QTY REQ'D PLUS 50
0	0	500
0	0	
0	0	
0	0	

0	0	MAX # CLINS PLUS 30- MAX # CLINS
		30

Figure 22. Basic Sealed Bid Model Layout (Aggregate Award - Part 3).

CONSTRAINTS:

	Required	Offeror 1 Complied	Offeror 2 Complied	Offeror 3 Complied	Offeror 4 Complied	Offeror 5 Complied	Offeror 6 Complied
Aggregate Award							
Is Restriction Required? (See Note)	Y						
Binary	1						
Is Aggregate Award Proposed?	FILL IN ->	Y	Y	Y	Y	Y	Y
Binary		1	1	1	1	1	1
	MET REQ?	Y	Y	Y	Y	Y	Y
Binary		1	1	1	1	1	1

(NOTE:)
IF Requirement = No, input "Y" but use also "Sealed Bid-Multiple" Worksheet to compare lowest of "Total Price" and "Evaluation Amount"

	Required	Offeror 1 Complied	Offeror 2 Complied	Offeror 3 Complied	Offeror 4 Complied	Offeror 5 Complied	Offeror 6 Complied
Small Business Restriction							
Is Restriction Required?	Y						
Binary	1						
Is Offeror a Small Business?	FILL IN ->	N	Y	Y	N	Y	Y
Binary		0	1	1	0	1	1
	MET REQ?	N	Y	Y	N	Y	Y
Binary		0	1	1	0	1	1

Figure 23. Basic Sealed Bid Model Layout (Aggregate Award - Part 4)

Offeror 5	Offeror 6	Total QTY	QTY Required
0	0	0	450
0	0	0	275
0	0	0	300
0	0	0	350
$0.00	$0.00	$0.00	Total Price

N	N
0	0

Admin. Fee	# of Awards	Evaluation Amount
$500	0	$0.00

Figure 24. Basic Sealed Bid Model Layout (Multiple Awards).

Table 8

Solver Parameters and Options (Sealed Bid – Aggregate and Multiple Awards).

PARAMETERS (Sealed Bid – Aggregate Award)

Set Target Cell:	J21
Equal to:	Min
By Changing Cells:	D17:I20, D26:I29, D32:I32
Subject to the Constraints:	
	D17:I20 = INT
	D17:I20 ≥ 0
	D26:I29 = BIN
	D26:I29 = INT
	D32:I32 ≤ D99:I99
	D32:I32 = BIN
	D32:I32 = INT
	D36:I39 ≤ 0
	D41:I41 ≤ 0
	J17:J20 ≥ K17:K20
	J26:J29 = 1
	J32 ≤ 1

PARAMETERS (Sealed Bid – Multiple Awards)

Set Target Cell:	J21
Equal to:	Min
By Changing Cells:	D17:I20
Subject to the Constraints:	
	D17:I20 = INT
	D17:I20 ≥ 0
	D25:I25 ≤ D85:I85
	J17:J20 ≥ K17:K20

SOLVER OPTIONS FOR BOTH MODELS

Assume Linear Model	Tolerance = 0%
Use Automatic Scaling	Iterations = 1000

Appendix D. FAR Part 15, Competitive Proposal SOLVER Model

Technical Acceptance								
Is Restriction Required?	Y							
Binary:	1							
Is Offeror in Compliance?	Factor 1	Y	N	N	Y	N	N	
Binary:		1	0	0	1	0	0	
	Met Req?	Y	N	N	Y	N	N	
Binary:		1	0	0	1	0	0	
IF ALL CONSTRAINTS ARE MET THEN = 1; IF NOT MET THEN 0		0	0	0	1	0	0	BIN<=CONST

Figure 25. Basic FAR Part 15 Model Layout (Technical Criteria Binary Constraint).

Frequency Conversion of Ratings

Overall Element Ratings

Offeror	1	2	3	4	5	6
Factor 1 -						
Subfactor 1						
Element 1	A	U	U	A	M	U
U M A	004	301	400	004	022	310
Element 2	A	M	M	A	M	M
U M A	004	031	121	004	040	130

All "U's" must be reviewed at lower level before rating

Binary Conversion of Overall Rating

Overall Subfactor Ratings

Offeror	1	2	3	4	5	6
Factor 1 -						
Subfactor 1	A	U	U	A	M	U
Binary:	1	0	0	1	0	0
Factor 1 -						
Subfactor 2	A	U	A	A	M	U
Binary:	1	0	1	1	0	0

If any "U" at this level, then "U"

Binary Conversion of Overall Rating

Overall Factor Ratings

Offeror	1	2	3	4	5	6
Factor 1	A	U	U	A	M	U
Binary:	1	0	0	1	0	0

If any "U" at this level, then "U"

Figure 26. Basic FAR Part 15 Model Layout (Technical Criteria Rating Charts).

Rating	Color	Values	Binary
Acceptable	A	1	1
Marginal	M	10	0
Unacceptable	U	100	0

Figure 27. Technical Criteria Ratings.

Table 9

Solver Parameters and Options
(FAR Part 15– Aggregate Award).

PARAMETERS

Set Target Cell:	I22
Equal to:	Min
By Changing Cells:	D18:I21, D27:I30, D33:I33
Subject to the Constraints:	
	D18:I21 = INT
	D18:I21 $\geq$ 0
	D27:I30 = BIN
	D27:I30 = INT
	D33:I33 $\leq$ D109:I109
	D33:I33 = BIN
	D33:I33 = INT
	D37:I40 $\leq$ 0
	D42:I42 $\leq$ 0
	J18:J21 $\geq$ K18:K21
	J27:J30 = 1
	J33 $\leq$ 1

SOLVER OPTIONS

Assume Linear Model	Tolerance = 0%
Use Automatic Scaling	Iterations = 1000

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13. ABSTRACT (*Maximum 200 Words)*

The strategic use of Information Technology in the acquisition field can be very useful in the decision-making process of evaluating alternative solutions during a Government source selection. Current implementation of information technology provides a more tactical approach to systems development. The use of Electronic Commerce/Electronic Data Interchange and the internet to electronically transfer information is only the beginning of the shift towards a more strategic design process for information systems within Government procurement agencies. A schematic model was designed to demonstrate how information technology, such as Decision Support Systems, Expert Systems, and Shared Data Warehousing could assist the SSA in selecting the optimal, or best value solution. In addition, three source selection evaluation models using management science techniques were designed and developed using Microsoft Excel software. The Sealed Bidding, FAR Part 14, and Competitive Proposal, FAR Part 15 models implemented Integer Linear Programming through Microsoft Excel's SOLVER option. The AFFARS Appendix AA/BB model implemented the use of the multi-criteria Analytical Hierarchy Process.

14. Subject Terms
Decision Support System, Expert System, Data Warehousing, Source Selection Evaluation Model, Integer Linear Programming, Analytical Hierarchy Process, Decision-Analysis, Multi-Criteria Evaluation, Scoring Models, Optimization, Evaluation Criteria.

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